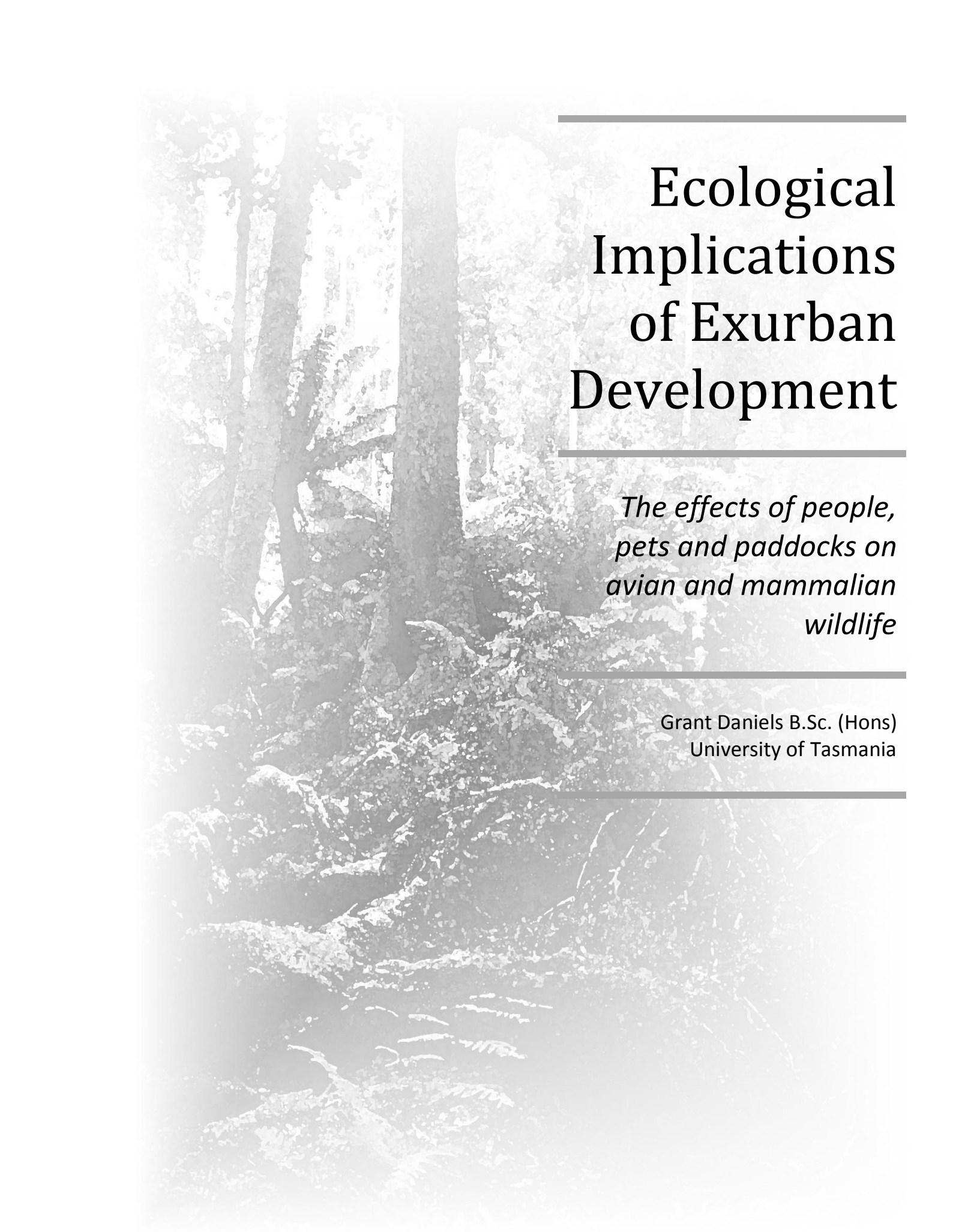

Ecological Implications of Exurban Development

The effects of people, pets and paddocks on avian and mammalian wildlife

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Broad-acre subdivisions on the fringe of cities constitute a relatively novel and rapidly increasing form of urban development known as exurbia. Despite the potentially significant effects exurban development can have on nature, no study has documented its effects on the distinct faunal communities of Australia. Within two exurban regions of Hobart, Tasmania, Australia, birds were sampled within discrete exurban habitats, exurban forest, modified forest, gardens, and paddocks, and corresponding wildland forests. Flightless mammals were surveyed by spotlight in the same environments. Landowners gave their opinions on a variety of nature-related issues. Their ownership of domestic mesopredators, participation in activities that might affect wildlife, and observations of wildlife were also recorded. Wildland bird species assemblages persisted within exurbia where the native canopy remained, but were displaced by synanthropes in gardens, and were strongly disadvantaged in paddocks. An aggressive small-bird-excluding edge species, the noisy miner, responded more strongly to historic rural clearance boundaries than to forest perforation and modification. In its absence, avian habitat specialists were not affected by the proximity or density of houses. Paddocks had more heterogeneous bird assemblages than expected. Overall, the native exurban avifauna was richer than the avifauna of both adjacent suburbs and control areas of native vegetation. Exurban landowners were comprised of four discrete attitudinal groups. Two of the groups were nature lovers, one was utilitarian, and the other was fearful of aspects of nature beyond their control, particularly unruly trees. The group with the strongest fear of trees had the highest level of tree cover on their property.

Attitudinal group was also associated with the distribution of some garden types, but not with landscape characteristics. Exurbanite attitudinal type had very little influence on the frequency or distribution of wild mammals observed by spotlight, but nature lovers were more likely to report observations of some species. Independent of attitudinal groups, the most detrimental landowner activity was pet ownership. Any detrimental effects of exurban domestic cat populations were unapparent due to the non-uniform distribution of cat owners and the presence of feral cats. Properties with dogs, however, were distributed more uniformly, and were avoided spatially and temporally by several species of mammal, including species that dog owners had not observed as prey. Within an isolated peninsula exurban region, the spatial avoidance of exurbia resulted in low numbers of those mammal species with large home range requirements. One species of bandicoot, however, was more common where houses were relatively dense. Overall, two very fecund mammal species, including a threatened native bandicoot, were more abundant in exurbia than in wildlands. For mammal conservation, houses may best be clustered in areas where access to wildland remnants is limited. This will slightly diminish the mammalian species diversity where residents live, but may be preferable to dispersed housing developments, which support greater species diversity than clustered developments, but will also distribute the effects of domestic mesopredators over a greater proportion of the landscape. Heterogeneous exurban landscapes are not necessarily detrimental for avifaunal conservation, as long as they include areas of undisturbed native vegetation, either in remnants or on exurban properties.

I would like to thank my family, my friends and my supervisors, all of whom have never failed to provide love and support.

This study would not have been possible without the generosity of exurban landowners, whose desire to promote exurban biodiversity was both inspiring and touching.

Introduction

From the 1970s, a significant proportion of Australia's residents moved from urban to rural areas, creating a rural population turnaround (Hugo, 1994; Walmsley *et al.*, 1998; Curry *et al.*, 2001). Although the turnaround may have slowed in some regions (Hugo, 1994), the areas beyond the fringes of Australian cities are still zones of relatively high population growth (Australian Bureau of Statistics, 2010). Similar population shifts have occurred in China (Tian *et al.*, 2007) and in the United States (Brown *et al.*, 2005). As a result of shifting populations, large areas formerly covered with wildlands or agricultural lands are now occupied by low density residential developments (Knight, 1999; Maestas *et al.*, 2002; Brown *et al.*, 2005; Tian *et al.*, 2007) known collectively as exurbia (Marzluff *et al.*, 2001).

The potential ecological implications of exurbanisation are manifold. Because both wildlands and agricultural lands can be exurbanised, often in immediate proximity to each other, there is the potential for exurban ecosystems to suffer the consequences of both habitat fragmentation and perforation (Miller *et al.*, 2001). Along with the juxtaposition of anthropogenic and natural habitats, exurbanisation may alter: population densities, species composition and distribution, disturbance regimes, and biogeochemical cycles (Dale *et al.*, 2005). Exurbia may also create different ecological problems to suburbia. Low housing density means that exurbia

requires more land per capita than urban and suburban zones, and thus potentially exposes a greater proportion of the landscape to the detrimental effects of urbanisation, leading to uncertainty over whether houses in fringe developments should be clustered or dispersed (Nilon *et al.*, 1995; Odell and Knight, 2001; Lenth *et al.*, 2006). In addition, due to socioeconomics (Tian *et al.*, 2007), and the attraction of natural amenities (Walmsley *et al.*, 1998; Hansen *et al.*, 2002; Rasker and Hansen, 2002; Holmes, 2006), exurban developments can expand, and be distributed, non-uniformly across the landscape (Hansen *et al.*, 2005; Tian *et al.*, 2007; Wade and Theobald, 2010), resulting in coincidence with sensitive ecosystems (Gonzalez-Abraham *et al.*, 2007) or local breeding hotspots (Hansen and Rotella, 2002). Thus, there is a potential for exurban developments to reduce the viability of wildlife populations in adjacent reserves (Hansen and Rotella, 2002).

The combination of rapid landuse transition and substantial potential implications for biodiversity, makes studies of exurban nature a high priority for nature conservation (Theobald, 2004). Despite this, exurban ecologies remain critically understudied, with ecologists focussing more on non-urban landscapes (Collins *et al.*, 2000; Miller and Hobbs, 2002; Adams, 2005). Studies of exurban nature are largely limited to a small number of North American studies on invertebrates (Bock *et al.*, 2006b; Bock *et al.*, 2007), mammals (Vogel, 1989; Harrison, 1997; Harrison, 1998; Odell and Knight, 2001; Maestas *et al.*, 2003; Bock *et al.*, 2006a; Bock *et al.*, 2006c; Lenth *et al.*, 2006; Storm *et al.*, 2007), avifauna (Odell and Knight, 2001; Maestas *et al.*, 2003; Lenth *et al.*, 2006; Bock *et al.*, 2008; Merenlender *et al.*, 2009), and plants (Maestas *et al.*, 2002; Maestas *et al.*, 2003;

Lenth *et al.*, 2006). The urban ecological literature is replete with studies of biota, avifauna in particular, along gradients of urbanisation or landuse intensity (McDonnell and Hahs, 2008). However, due to the varied terminology used to describe levels of urbanisation, and the failure of many studies to follow standard definitions of, or elucidate the measures used to quantify, levels of urbanisation (Marzluff *et al.*, 2001; McDonnell and Hahs, 2008), it is difficult to conclusively determine which studies include exurban sites. Certainly at least one Euro-Canadian (Clergeau *et al.*, 1998) and three American (Nilon *et al.*, 1995; Hansen and Rotella, 2002; Haskell *et al.*, 2006) studies of avifauna, and one Australian study of plants (Williams *et al.*, 2005), include exurban sites. In addition to these ecological observations, some studies have documented the attitudes and opinions of exurban residents on matters of nature conservation (Harrison, 1998; Woolcott Research, 2002; Storm *et al.*, 2007).

Most of the observational studies above were conducted in treeless rangelands and compared elements of biodiversity to both housing density and grazing intensity, because of the 'cows vs. condos' debate (Knight *et al.*, 1995). This is a situation not entirely relevant to Tasmania, where treeless exurban vegetation is predominately comprised of exotic plants, due to widespread conversion of native grassy ecosystems following European colonisation (Kirkpatrick *et al.*, 1988). Nonetheless, these studies have documented some significant ecological implications of exurbanisation, many of which conform with well known responses of biodiversity to urbanisation overall.

Exurbanisation can cause shifts in species dominance within taxa (Vogel, 1989), sometimes resulting in greater abundances of dietary generalists (Bock *et al.*, 2007) and birds that are cavity nesters, granivores, and / or aggressive edge species (Nilon *et al.*, 1995; Odell and Knight, 2001; Bock *et al.*, 2008), all of which can result from urbanisation in general (Pickett *et al.*, 2001; Adams, 2005; Chace and Walsh, 2006).

Species exhibit varied responses to exurban housing proximity (Vogel, 1989; Harrison, 1997; Harrison, 1998; Odell and Knight, 2001; Bock *et al.*, 2006a), but the majority of species studied appear to decline in number with increasing exurban housing density (Vogel, 1989; Odell and Knight, 2001; Bock *et al.*, 2008), as many species do along more extensive gradients of urbanisation (Adams, 2005; Chace and Walsh, 2006).

Because a greater proportion of natural vegetation remains within exurban landscapes, they could be expected to be less homogenising than urban areas, resulting in strong regional variations in biotic responses. Indeed, the effects of exurbanisation can vary between ecosystems. Within naturally treeless habitats, exurbanisation can benefit species that utilise trees for nesting (Maestas *et al.*, 2003) or shade (Bock *et al.*, 2007), are dependent on dense shrub cover (Bock *et al.*, 2006a), or are nectivorous (Maestas *et al.*, 2003; Bock *et al.*, 2007). All of these responses are suspected to result from exurban gardens and / or landowners providing limiting resources (Maestas *et al.*, 2003; Bock *et al.*, 2007). However, with Lepidopterans at least, if habitats that have naturally higher levels of shade and vegetation complexity than arid grasslands are exurbanised, then the resources that accompany exurbanisation are not sufficient to offset habitat loss (Bock *et al.*, 2007).

Similarly, shrub or ground nesting birds suffer from exurbanisation of arid rangelands (Maestas *et al.*, 2003), but not from exurbanisation of forest habitats (Haskell *et al.*, 2006).

Variable responses to exurbanisation could be a result of more than resource distribution in the exurban matrix. The influence of detrimental processes, such as pesticide use and avian predation, are also potentially significant (Bock *et al.*, 2007), and are likely to vary between habitats. High predation rates in open grassland habitats could be primarily responsible for the predominance of multivoltine butterflies in such habitats (Bock *et al.*, 2007), because fecund species are capable of maintaining viable population sizes whilst suffering high levels of mortality (Pimm *et al.*, 1988). Because the effects of exurban development can vary between ecosystems, regional comparisons of exurban ecology are needed in order to determine the types of ecosystems that are particularly vulnerable (Hansen *et al.*, 2005).

Exurbanisation can have significant effects on mammalian predator assemblages. Native mesopredators are significantly outnumbered by domestic mesopredators in exurbia (Odell and Knight, 2001; Maestas *et al.*, 2003), creating the potential for resource competition and interspecific aggression (Jones *et al.*, 2003). Relative to conspecifics in natural habitats, mesopredators within exurbia have been found to be heavier, perhaps because of the anthropogenic food they consume (Harrison, 1997), to be less active diurnally (Harrison, 1997) (as are exurban deer (Vogel, 1989)), to consume proportionately more meat (Harrison, 1997), probably an opportunistic dietary shift in response to prey abundances, just as domestic

mesopredators are known to do (Coman and Brunner, 1972; Barratt, 1997b); and to have greater variation in home range sizes (Harrison, 1997), which suggests a non-uniform distribution of resources and / or competing domestic predators within exurbia.

Rates of plant extinction have been found to be lower in exurbia than in more urbanised areas (Williams *et al.*, 2005). Native forb richness can actually increase with exurbanisation, because some species benefit from exurban disturbance regimes (Bock *et al.*, 2006b; Bock *et al.*, 2007), just as a variety of ephemeral species are known to occupy disturbance niches in numerous anthropogenic habitats (Kirkpatrick, 2007). However, exurban areas can also have significantly more exotic, and less native, species of plants than stock ranches (Maestas *et al.*, 2003), suggesting that native plants can benefit from stock that preferentially graze exotics.

There are demonstrably substantial ecological implications of exurban development, but not all implications are necessarily detrimental to biodiversity, or at least certain lifeforms. Exurban residents are largely positive towards wildlife and matters of nature conservation (Harrison, 1998; Woolcott Research, 2002), and have a strong awareness of potentially detrimental consequences of urbanisation, such as: the application of pesticides, the lack of suitable habitat, and the presence of domestic predators; and agree that more should be done to ameliorate these threats to wildlife (Woolcott Research, 2002). In addition, exurban land management, such as grazing regimes, can promote certain lifeforms (Bock *et al.*, 2006b; Bock *et al.*, 2007), and other techniques, such as food and water provision and selective planting, are possibly favouring others (Maestas *et al.*, 2003). Thus, given that rare

and threatened species can survive in, and colonise, urban areas (Kirkpatrick *et al.*, 1988; Dufty, 1994a; Ashworth, 1998; Pyke and White, 2001; Low, 2003; Kirkpatrick, 2007; Sorace and Gustin, 2010), and that private landowners want to do more for nature conservation, exurbia may provide significant opportunities for biodiversity conservation.

There are several questions that need to be addressed. How do the avifaunal and mammalian assemblages of Australian exurban landscapes compare to those that would have occupied the sclerophyll forests prior to development? Domestic mesopredators are evidently prevalent in exurbia – are they significantly influencing the distribution of exurban fauna? Can pet control mitigate their impacts? Can landowners affect exurban fauna through processes such as garden chemical application and habitat alteration? Do exurban ecologies vary between sclerophyllous forest ecosystems at opposite ends of a precipitation gradient? How can exurban development be made more ecologically sustainable?

Thus, the present study will investigate the responses of flightless mammal and avifaunal communities to exurban development on the fringe of Hobart, Tasmania, Australia. As this is the first study of exurban wildlife ecology in the southern hemisphere, the null hypothesis is that exurban subdivision in Australia does not affect flightless mammal and avifaunal communities. It will provide comprehensive data on the distribution of fauna throughout exurban Hobart, and nature conservation guidelines for exurban planners and landowners.

Thesis structure

Chapter two describes the exurban study area, including: the extent of land clearance and forest perforation; the major natural and anthropogenic vegetation communities; the location of representative wildland control sites; and the methodology used in attaining permission to survey exurban properties.

Chapter three documents variation in bird species assemblages due to exurbanisation, including the influences of habitat modification and variation, the presence of aggressive edge species, and the process of homogenisation.

Chapter four compares flightless mammal assemblages in exurbia to those in wildlands. The influence of exurban property and landscape characteristics are tested, and species adaptability to the exurban landscape is correlated with life history traits.

Chapter five explores sociological diversity among exurbanites and tests the influence of group attitudes and independent human activities on the distribution of wild exurban mammals.

Chapter six summarises the main findings of the study, identifies areas where more research is needed, and outlines some prescriptions for improving nature conservation in existing and future exurban developments, as well as urban areas in general.

Study area - Exurban Hobart

The two areas chosen for study contain a large proportion of the exurban fringe of the city of Hobart, Tasmania, Australia. Area one is comprised of the neighbouring suburbs of Sandford and Clifton Beach on the South Arm Peninsula (hereafter referred to as 'South Arm'), and area two the contiguous areas of Leslie Vale, Longley, Neika and Sandfly (hereafter referred to as 'Kingborough'). South Arm is situated east of Hobart and receives between 300 and 600 mm of precipitation per annum. Kingborough is located south of Hobart, adjacent to, and partially encompassing the slopes of, Mount Wellington. Mean precipitation in the area ranges between 800-1100 mm per annum.

Respectively, South Arm and Kingborough are located within the local government areas (LGAs) of Clarence and Kingborough, which are two of the fastest growing LGAs in Tasmania (Australian Bureau of Statistics, 2010). Each of these LGAs is directly adjacent to the metropolitan LGA of Hobart, making the exurban regions of South Arm and Kingborough forms of urban fringe development, rather than rural residential development (Hansen *et al.*, 2005). However, the areas have some of the characteristics of rural residential development, such as proximity to public lands, and natural amenities such as coastal views, both of which result from Hobart's polycentric pattern of urbanisation, which is due to terrestrial and topographic

constraints, and results in water and reserved lands being juxtaposed with both metropolitan and exurban regions.

South Arm constitutes an area of 5674 ha, of which, 1399.5 ha is covered by 728 residential properties at suburban or exurban densities. All the suburban properties within South Arm are located within two discrete clusters, a classic example of how the level of urbanisation is not linearly correlated with distance from city centre (Alberti *et al.*, 2001). If the two discrete suburban zones are excluded, 1358.8 ha of South Arm is exurban and is comprised of 542 residential properties with a mean area of 2.51 ha.

Of the non-urban land in South Arm, of which there are 4274.5 ha, approximately 1084 ha constitute forested wildland remnants, most of which are in two 300+ ha patches. Less than 50 ha of the wildland remnants are isolated by land clearance; the remainder are isolated not by land clearance, but by forested exurban properties. Thus, tree cover connectivity remains high, but heavily perforated and parcellated. In total, 37 % of South Arm remains forested, with close to 49 % of this occupied by exurban development (Figure 1). South Arm is isolated from extensive wildlands (> 500 ha) by suburban density development and the sea.

Kingborough constitutes an area of 4341 ha, of which 2240 ha is covered by exurban properties with a mean property size of 4.2 ha. Of the 2101 ha of non-urban land in Kingborough, 1312 ha constitutes forested wildland remnants. As in South Arm, most of these wildlands are isolated from other wildlands by forested exurbia, rather than cleared land. In total, 2865 ha (66 %) of Kingborough remains forested, with 1553 ha of this perforated by exurban development (Figure 2).

Figure 1: South Arm 2004. Map grid: GDA 94.

Figure 2: A representative section of Kingborough in 2004. Map grid: GDA 94.

Within the exurban study area, landowners residing on blocks between 2-4 hectares in size were approached through door knocking, and permission sought to conduct field work on their property. While the sample of properties could not be random, because of refusal and absences of owners when requesting access, there was a high willingness among owners to allow data collection on their property. This resulted in permission being granted to conduct work on an array of properties representative of the local exurban landscape, ranging from completely cleared properties, to houses embedded within forest. In total, the owners of 89 exurban properties gave consent for research to be conducted, and stated their willingness to complete the questionnaire.

Natural vegetation

Natural vegetation in both the South Arm and Kingborough areas predominately consists of forests dominated by *Eucalyptus* species. Because factors such as soil water-flow and solar radiation can influence forest community composition as much as precipitation (Kirkpatrick and Nunez, 1980), some forest types occur in both regions (Figure 3). However, the precipitation gradient is evident in the predominance of broad-leaved 'ash' and 'gum' eucalypts in Kingborough compared to narrow-leaved 'peppermint' eucalypts that dominate most South Arm forests. To quantify this, the dominant tree species were assessed at randomly located forest points within Kingborough (n = 50) and South Arm (n = 50). Kingborough had a significantly greater proportion of sites with a dominant canopy of broad-leaved eucalypts (Pearson's Chi-Square = 31.818, df = 1, P = 0.000). Consequently, a greater proportion of Kingborough forests have dense understoreys dominated by a mixture

of scleromorphic and broad-leaved small trees and tall shrubs, as typically accompanies broad-leaved eucalypts in high rainfall regions (Kirkpatrick *et al.*, 1994). South Arm forests have open understoreys variously dominated by scleromorphic shrubs or tussock graminoids.

Figure 3: A representative sample of some of the forest types found within exurban Kingborough and South Arm. Top line: silver peppermint forests restricted to South Arm; Middle line: forest types found in both regions; Bottom line: ash forests with broad-leaved understoreys restricted to Kingborough.

Habitat classifications

Throughout the thesis, a number of terrestrial and one aquatic habitat are referred to regularly. These are defined below. Because exurbia is a heterogeneous landscape, wildlands is the only habitat type in which data collection sites were necessarily embedded within homogeneous areas. In addition, the scale at which an area is considered can influence its classification. Bird survey sites were 625 m^2 and only the vegetation within that area necessarily conformed to the definitions below (see Chapter 3 for more details).

Wildlands

Wildlands refer to areas of undeveloped natural vegetation in large remnants (> 400 ha). Importantly, these are not wildland remnants within exurbia, like those mentioned above, but are wildlands located away from any urban influence, and thus broadly representing the situation before forests were fragmented and perforated. Wildland study sites corresponding to exurban forest types were located within: Coningham Nature Recreation Area, Meehan Range State Recreation Area, Wellington Park, and Woodvine Nature Reserve. Data collection within wildlands was conducted no less than 250 m from the forest edge, and a minimum of 500 m from any dwelling.

Exurban forest

Exurban forests constitute unmodified naturally occurring forest vegetation located within exurbia. The structure and floristics of exurban forests do not markedly differ from representative wildland forest communities.

Modified forest

Modified forests constitute exurban forests that have had between 25 and 100 % of their understorey vegetation modified structurally by clearance or ongoing periodic suppression (slashing, stock grazing). This understorey modification can result in the exposure of surface soil or the establishment of a grassy sward (Figure 4). Tree clearing is often evident, but not extensive, and often results in the broadening of the crowns of the remaining trees. Thus, canopy cover is comparable to that in corresponding wildland and exurban forests, but sometimes constitutes fewer individual trees, which further contributes to the openness of the understorey.

Figure 4: Types of forest modification in exurbia. Top line, left to right: exurban forest; modified forest in foreground grading into exurban forest in the background. Bottom line, left to right: modified forest with grassy understorey; modified forest with exposed soil.

Grassy woodland

Grassy woodlands are comprised of scattered indigenous trees (10 % coverage) from the genera *Eucalyptus*, *Acacia* and *Allocasuarina*, over a grassy sward.

Saltmarsh

Treeless vegetation dominated by succulent chenopods and aizoans.

Dune grassland

Treeless sand dune vegetation dominated by tussocks of *Ammophila arenaria*.

Paddocks

Paddocks are exurban sites largely devoid of woody vegetation (< 5 % total cover) (Figure 5). Paddocks have a dominant stratum < 60 cm in height comprised predominately of self-sustaining grasses and herbs. Paddocks were subdivided into two classes, based largely on maintenance and the presence of non-grassy graminoids.

Pasture paddock: regularly grazed or mowed paddocks with grassy swards typically less than 30 cm in height.

Rank grass / tussocky paddock: infrequently suppressed grassy thickets interspersed with clumps of rigid monocots from genera such as *Lomandra*, *Gahnia* and *Juncus*.

Gardens and lawn

Lawn: A grassy area adjacent to a house that is visibly regularly maintained through mowing, and ostensibly weeding, watering and fertilising.

Figure 5: Exurban paddocks. Top line: pasture paddocks in foreground grading into grassy woodlands. Bottom line, left to right: pasture paddock foreground, windbreak in middle-ground, hill in background includes exurban forest on right, and modified forest on left; rank grass and tussocky paddock with forest in background.

Gardens are non-natural exurban sites created by the deliberate planting of ornamental and / or productive species of plants. Exurban gardens are generally located adjacent to a homestead. Bird survey sites within garden habitats often included an area of maintained lawn, but garden plants covered > 25 % of the survey area.

Thirteen garden types are found in the city of Hobart (Daniels, 2005; Daniels and Kirkpatrick, 2006a). For the present study the 13 garden types were grouped into five classes.

Mixed minimal input gardens: A mostly exotic garden community with intermediate levels of shrub and forb cover, and very low percentage of tree cover. Indicator species include *Pittosporum* spp. and *Photinia glabra*, *Cotoneaster* spp., *Crocosmia crocosmiiflora* and *Lunaria annua*. Native species are generally shrubs from the genera *Callistemon* and *Grevillea*.

Showy flower gardens: A largely exotic, speciose, herbaceous garden type. Infrequently includes small evergreen trees, but uniformly includes spectacular flowering perennials and annuals. Indicator species include: *Alonsoa warscewiczii*, *Chrysanthemum grandiflorum*, *Coleonema pulchrum*, *Gazania* spp., *Drosanthemum candens*, *Cotyledon orbiculata*, *Festuca glauca*, *Heuchera* spp., *Mimulus* spp., *Cymbalaria muralis*, *Kalanchoe* spp. and *Lithodora diffusa*.

Native gardens: A species rich Australian native garden with very few deciduous trees, high levels of native tree cover, and large proportions of shrub cover. Indicator species include: *Baloskion tetraphyllus*, *Correa alba*, *Correa reflexa*, *Leptospermum scoparium*, *Prostanthera* spp., *Kunzea ambigua*, *Leptospermum lanigerum*, local *Eucalyptus* spp. and *Pomaderris* spp.

Productive gardens: An exotic garden type comprised predominantly of productive fruit bearing species and culinary herbs. Indicators species include *Solanum tuberosum*, *Lactuca sativa*, *Olea europea*, *Citrus* spp., and *Allium* spp.

Woodland gardens: A diverse garden type with high levels of deciduous tree cover and a complex exotic understorey that is occasionally complemented with productive plants such as tomatoes, brassicas, and globe artichokes. Indicator species include *Acanthus mollis, Cyclamen* spp., *Acer* spp., *Magnolia* spp., *Philadelphus* spp. and *Garrya elliptica*.

As well as the garden types also found in suburban Hobart, the exurban fringe contains anthropogenic habitats that do not occur in suburbia: orchards and shelter-belts.

Orchard: A collection of variously spaced large shrubs / small trees that produce a harvest of edible fruits or nuts. Exurban orchards generally include species of the genera *Malus* and *Prunus*, and less frequently include *Cydonia oblonga*, *Ficus carica* and *Pyrus communis*, but plantings including many more species could also be classified as orchards (e.g. *Castanea sativa*, *Morus* spp., *Olea europea*). Apart from the occasional companion plant, orchard understoreys are largely devoid of non-grassy species, and are frequently mulched to deter understorey vascular vegetation growth (as well as to maintain moisture). This impoverished understorey separates orchards from the productive garden types outlined above, which can include the full complement of fruit-bearing species found in orchards.

Windbreak (shelter-belt, hedgerow): A linear planting of trees and large, potentially arborescent, shrubs. Distinct from gardens due to: the absence of small shrubs and herbaceous plants, and the location of the planting (windbreaks are generally distant from houses, being more frequently associated with fence lines and aesthetically unappealing structures on neighbouring properties.

Dams

The terrestrial exurban landscape is perforated with numerous anthropogenic water-bodies variously referred to as ‘ponds’ or ‘dams’. Although pond is probably the most appropriate terminology, as exurban water-bodies are essentially small lakes, rather than impoundments, or impediments to water flow, they are referred to as dams throughout the entire thesis, as this is the name used by local people, and also avoids confusion with the occasional tiny water-bodies placed within gardens to attract frogs, which are universally referred to as ponds. Throughout the thesis, any water-body referred to as a dam conforms to the following definition: an earth-based anthropogenically created depression that periodically, or permanently, holds water and has a width or diameter in excess of 2 m and a down-slope earth wall between 0 cm and 2 m high. Dams that remained permanently dry throughout the course of the study were not included in any dam analyses.

Exurban dam vegetation varied markedly. Some were intentionally planted out with ornamental plants adapted to poorly-drained soils. Many others were colonised by opportunistic riparian graminoids and aquatic angiosperms of varying origin. Others had an impoverished perimeter of mud, which can result from large periodic water level fluctuations.

Avifaunal responses to exurbanisation

Introduction

Altered faunal and floral species composition are a logical consequence of urbanisation and exurbanisation (Odell and Knight, 2001; Maestas *et al.*, 2002; Adams, 2005; Bock *et al.*, 2006a; McKinney, 2006; Bock *et al.*, 2008). Urban areas typically support species-poor avifaunal communities (Marzluff, 2001; Chace and Walsh, 2006). However, exurban bird species communities can be at least as rich (Nilon *et al.*, 1995), or richer than, wildland communities (Bock *et al.*, 2008), and, in some cases, can even harbour more species of conservation concern (Haskell *et al.*, 2006). Exurban landscapes are typically heterogeneous (Nilon *et al.*, 1995; Hansen and Rotella, 2002; Haskell *et al.*, 2006; Bock *et al.*, 2008). High biodiversity results from habitat heterogeneity at a variety of spatial scales (Law and Dickman, 1998; Pickett *et al.*, 2001; Benton *et al.*, 2003; Marzluff, 2005; Mayfield and Daily, 2005). Thus, exurban heterogeneity is thought to enable disturbance-sensitive and disturbance-adapted species to co-exist (Odell and Knight, 2001; Lenth *et al.*, 2006), which results in a diverse avifauna and non-uniform bird species assemblages across the wildlands – exurban interface (Haskell *et al.*, 2006).

Within single exurban habitats, it seems plausible that the low housing density that defines exurbia could result in minimal disturbance to bird communities, enabling wildland assemblages to inhabit exurban zones. However, when habitat

heterogeneity is controlled for, at least at the local scale, exurban bird communities in the USA are still generally discrete from wildland communities. Broadly, these exurban habitats harbour fewer forest migrants (Nilon *et al.*, 1995; Merenlender *et al.*, 2009) and songbirds (Odell and Knight, 2001), and higher abundances of certain nest predators or parasites (Nilon *et al.*, 1995; Hansen and Rotella, 2002), than representative wildlands.

Avifaunas within Australian exurban landscapes have not been studied. Exurbanisation could affect Australian avifauna differently than American avifauna, because biotic responses to exurbanisation vary between ecoregions (Hansen *et al.*, 2005; Bock *et al.*, 2007) and Neotropical migrants are particularly vulnerable to forest fragmentation (Ambuel and Temple, 1983; Lynch and Whigham, 1984; Blake, 1991). Comparisons with suburban Australia, however, reveal similar shifts in species composition as those observed in exurban USA, such that Australian suburban bird communities are distinct from those observed in wildlands (Munyenyembe *et al.*, 1989; Parsons *et al.*, 2003) and in forest remnants within an urban matrix (Jones, 1981; Catterall *et al.*, 1989; Wood, 1996; White *et al.*, 2005; Iijima, 2009).

The distribution of urban avifauna varies in accordance with plant species composition (Green, 1984; Tweit and Tweit, 1986; Mills *et al.*, 1989; Day, 1995; Fitzsimons *et al.*, 2003; Daniels and Kirkpatrick, 2006b; Parsons *et al.*, 2006). Therefore, it is not surprising that distinctly-suburban bird species assemblages inhabit predominately exotic streetscapes (White *et al.*, 2005). However, streets with native vegetation (White *et al.*, 2005), and suburbs with a largely retained native tree canopy (Sewell and Catterall, 1998), have also been found to harbour bird species

assemblages significantly different to those observed in wildlands. Specifically, Australian suburban bird communities have proportionally fewer small-bodied insectivores and nectivores, more exotics, and more medium-to-large-bodied generalists and nectivores (Jones, 1981; Green, 1986; Wood, 1996; Sewell and Catterall, 1998; Parsons *et al.*, 2003; White *et al.*, 2005).

Some large-bodied Australian-native synanthropes, the noisy miner in particular, are interspecifically aggressive, which potentially confounds the identification of causal relationships between urbanisation and bird communities. Noisy miners, which consistently co-occur with other edge species, such as Australian magpies, rosellas, grey butcherbirds and lorikeets (Catterall, 2004), alter the composition of bird species communities even in non-urban habitats by aggressively excluding smaller-bodied species from their territory (Dow, 1977; Grey *et al.*, 1997; Grey *et al.*, 1998; MacDonald and Kirkpatrick, 2003; Maron, 2009) and predating their nests (Piper and Catterall, 2004).

While the abundance of some edge species are positively correlated with remnant (Bellamy *et al.*, 1996), and exurban (Nilon *et al.*, 1995), forest perimeters, not all edge species respond to the spatial modification of exurban forests at the same scale or rate (Nilon *et al.*, 1995), making their presence in urban habitats contextual. Indeed, the urban distribution of the Australian edge assemblage, and noisy miners singly, has been shown to be primarily influenced by landscape level, rather than site, characteristics (Parsons and Major, 2004; Daniels and Kirkpatrick, 2006b; Parsons *et al.*, 2006).

Natural habitat for noisy miners and their cohort is dry open eucalypt woodland, because it is more difficult to exclude other species from structurally complex vegetation (Dow, 1977; Maron, 2009). They also favour forest remnants with high perimeter-to-area ratios (Catterall *et al.*, 1997; MacDonald and Kirkpatrick, 2003; Catterall, 2004). Typically, miners occupy urban habitats when suburban vegetation physiognomically resembles natural habitat, such as grassy suburbs with a largely retained indigenous canopy (Sewell and Catterall, 1998), or when suburbs are proximal to the coast and / or small remnants of natural habitat (Green, 1986; Parsons *et al.*, 2003; Parsons and Major, 2004; White *et al.*, 2005; Daniels and Kirkpatrick, 2006b). In addition, anecdotal evidence suggests that perforation of dry woodland habitat for residential housing creates points of invasion for miners (Dow, 1977). This is supported by the finding that picnic area perforations are occupied by noisy miners and their cohort (Piper and Catterall, 2006). Thus, the coastal location, the extent of forest perforation, and the dry open vegetation, make South Arm inherently suitable for edge species. As a result, bird assemblages in South Arm were predicted to be distinct from wildland assemblages.

Edge species were expected to be present at significantly lower densities in the relatively dense inland forests of exurban Kingborough. The implications of exurbanisation on avifauna are less apparent in areas without edge species. Suburban gardens in miner-free regions can harbour a diverse assemblage of small woodland birds (Daniels and Kirkpatrick, 2006b), but these still mostly lack a number of species shown to be sensitive to habitat alteration and urbanisation, such as grey shrike-thrushes, grey fantails, golden whistlers, superb fairy-wrens, striated

pardalotes, satin flycatchers, yellow-throated honeyeater and the Tasmanian scrubwren (Jones, 1981; Green, 1986; Ford and Barrett, 1995; Wood, 1996; Catterall *et al.*, 1998; Catterall, 2004; White *et al.*, 2005; Piper and Catterall, 2006; Iijima, 2009). It is generally accepted that urban areas lack the necessary complex understorey vegetation to support these species (Garden *et al.*, 2006).

Exurbanisation is suspected to have less impact on biodiversity than traditional forms of urban development (Marzluff, 2001), because exurbia intrinsically differs from suburbia in the extent of remaining natural habitat and lower housing density, which enables disturbance-sensitive species to occupy exurbia (Odell and Knight, 2001; Bock *et al.*, 2008). Nevertheless, the threshold of some species' sensitivity to urban-associated disturbance and habitat alteration may be below even exurban levels, and thus, even in the absence of edge species, they may be out-competed by typical anthropophiles, resulting in lower species richness, greater bird abundance, and an assemblage of adaptable generalists, consistent with classic urban avifaunas (Beissinger and Osborne, 1982; Green, 1986; Catterall *et al.*, 1989; Jokimaki and Suhonen, 1993; Clergeau *et al.*, 1998; Melles *et al.*, 2003).

An additional aspect of the changes to bird species composition that result from urbanisation, is bird community homogenisation between sites within habitats, between habitats within regions, and between habitats across regions.

Despite the non-uniform bird species assemblages that can result from varied suburban plant communities (Melles *et al.*, 2003; White *et al.*, 2005; Daniels and Kirkpatrick, 2006b; van Heezik *et al.*, 2008), levels of similarity between bird species communities of suburban sites have been found to be higher than the levels of

similarity between the communities of wildland or remnant sites (Parsons *et al.*, 2003; White *et al.*, 2005). Within suburbia, similarity between sites has been found to be highest in streetscapes with exotic vegetation, lower in recently developed streets largely devoid of woody vegetation, and lowest in streets with native vegetation (White *et al.*, 2005). If this pattern is evident within exurbia, intersite similarity can be expected to be highest in gardens, lower in paddocks, and lowest in forest habitats.

While landscape characteristics determine the general location of noisy miner territories (Parsons and Major, 2004; Daniels and Kirkpatrick, 2006b; Parsons *et al.*, 2006), within their territory, bird species assemblages can be uniform, despite typical variance in urban vegetation (Parsons *et al.*, 2003). This suggests that miners patrol, and practice interspecific aggression in, local patches of sub-optimal habitat. Thus, bird species assemblages within South Arm habitats were expected to be more homogeneous than in Kingborough, and, potentially uniform, irrespective of habitat.

Regional similarities in bird species communities typically increase with the level of urbanisation or land use intensity, but not necessarily in a monotonic fashion (Clergeau *et al.*, 1998; Blair, 2001; Jokimaki and Kaisanlahti-Jokimaki, 2003; Blair, 2004; Clergeau *et al.*, 2006; Blair and Johnson, 2008; Sorace and Gustin, 2008). Specifically, human-managed habitats are more similar regionally than non-managed habitats (including those with a history of land clearance) (Blair, 2001; Blair, 2004; Blair and Johnson, 2008). Although the non-uniform distribution of edge species across the current study area may confound regional differences, they could still be expected to follow the same patterns of similarity as other cities, but with lower

similarity values. Thus, if managed habitats are more similar than non-managed habitats, gardens will be expected to have higher levels of regional similarity than paddocks, exurban forests, and wildlands.

The trend in regional similarity may reflect the proximal causes of avifaunal homogenisation. High regional similarity in gardens may suggest that the level of exposure to human activity is the proximal cause of homogenisation, due to garden proximity to houses. If the alteration of vegetation physiognomy is the proximal cause of avifaunal homogenisation, then regional similarities could be expected to increase along a gradient from wildlands and exurban forests through to paddocks, with modified forest and gardens potentially overlapping due to variable structural complexity in gardens in particular. If changes to the species composition of vegetation are the proximal cause of regional homogenisation, then regional similarities may not be evident at all within the current exurban study area, because the composition of exurban forests and paddocks are largely dependent on environmental conditions, and exurban gardens in the South Arm region, despite being maintained to some extent, largely consist of drought hardy gardens (Kirkpatrick *et al.*, 2007).

This chapter will be the first Australian study to document variation in bird species assemblages due to exurbanisation. The bird species assemblages found within distinct exurban habitats, exurban forest, modified forest, gardens, and paddocks, will be compared to, each other, representative wildlands, and to regional counterparts. Several questions are investigated. (1) Does the presence of edge species in exurbia result in bird species assemblages that are discrete from wildland

assemblages and more homogeneous than regional exurban counterparts? (2) In a region without aggressive edge species, does exurbanisation alter forests to such an extent that anthropophiles displace urban-sensitive species, resulting in a typical urban avifauna, or does the low housing density and high tree cover in exurban estates enable wildland bird species assemblages to persist? (3) If bird species communities change in response to exurbanisation, are some species extirpated from the exurban landscape? (4) Does the exurban landscape contain non-uniform bird species assemblages that vary in accordance with habitat variation? (5) Are certain guilds of species particularly sensitive to exurbanisation or restricted to certain exurban habitats? (6) Are regional similarities higher in gardens than lesser-managed habitats? (7) Do levels of similarity between sites within habitats conform to patterns previously observed in suburban regions?

Methods

Bird survey sites and sampling

Stationary point counts satisfy the criteria for assessing the effectiveness of a bird survey method in any given situation (Hewish and Loyn, 1989), and are particularly effective at quantifying bird-habitat associations (Bibby *et al.*, 2000). Thus, a total of one hundred and sixty-four square or rectangular survey plots, 625 m^2 in area, were located across South Arm (n = 73), Kingborough (n = 71) and representative forested wildlands (n = 20). Within exurbia, sites were distributed across the four most prominent exurban habitats: exurban forest (n = 37); modified forest (n = 39); gardens (n = 33); and paddocks (n = 35). Plots were angular rather than radial,

because square shapes better fitted the shapes of exurban gardens and paddocks. Relatively small sized sampling plots (625 m^2) were used as a way to ameliorate variations in bird detection probability between sites with varied structural complexity.

In addition to standardising through fixed-area, bird sampling was also standardised through fixed-effort. Between the dates of 08/06/06, and 21/08/08, a total of seven 20-minute point count surveys were conducted at each site. Each site was surveyed four times during the morning period (dawn – 11 am), three times during the afternoon period (2:30 pm – dusk), twice during the southern hemisphere spring months (September – November), twice during the summer months (December – February), once during the autumn months (March – May), and twice during the winter months (June – August). Bird surveys were not carried out in rain, or when wind was sufficient enough to be a potential hindrance to accurate identification (Ratkowsky and Ratkowsky, 1979).

During each survey, quantitative counts of each species seen and / or heard within the site were conducted by a single observer (author). Birds flying over or through the site were not recorded, except for aerial insectivores which were included if foraging within 5 m of canopy height or below. Fixed-area quantitative bird surveys, especially those as long as 20 minutes, suffer the risk that individual birds will be counted twice as they move in and out of the survey area. To avoid erroneous estimates of bird abundance that could result from this, bird species abundance for any given survey was equal to the greatest number of individuals of that species present in the site at any one time. The only (but frequent) exceptions

to this procedure were occasions when it was unmistakable that an individual in the site was different to a prior recorded individual, such as when a prior recorded individual was still visible outside of the survey limits, or was morphologically distinctive due to sexual or age-related dimorphism.

The precise location from which the observer conducted the point count varied between sites, but remained constant within sites over time. Ideally the observer location maximised site visibility and minimised observer conspicuousness. In densely vegetated sites this tended to be a location immediately adjacent to, or within, the survey area, whereas in sparsely vegetated sites, the location was generally a short distance (20 m) away from the plot, preferably next to something that afforded the observer some level of concealment.

Active bird nests were noted when encountered, at any stage throughout the project, within the entire exurban study area or within any relevant vegetation community in the wildland locations. For each nest, bird species, nest plant species or structure, and nest location, were recorded.

Site vegetation and locale

Within each of the bird survey plots, the following site variables were documented:

- Vascular plant species richness – all observable species were noted once during summer (southern hemisphere) 2006 / 2007 and then ephemeral or geophytic species were added if encountered at other times, giving a complete list of vascular plant species present throughout the study period.

- The tallest plant, as well as the mean height of the tallest stratum with ≥ 20 % cover was scored in the categories: 0 - 30 cm; 30 cm – 2 m; 2 m – 4 m; 4 – 8 m; 8 – 40 m.
- Percentage cover of: evergreen trees (woody evergreen plants over 8 m in height); deciduous trees (deciduous plants > 8 m in height); small trees (woody plants between 4 and 8 m in height) large shrubs (woody plants over 2 and less than 4 m in height); small shrubs (woody plants less than 2 m in height); grass; forbs; ferns and non-grassy graminoids collectively; artificial surfacing (concrete, small buildings, swimming pools, etc.); were recorded by visual estimation into the categories: 0 – 5 %, 5 – 10 %, 10 – 25 %, 25 – 50 %, 50 – 75 %, 75 – 100 %.
- The presence of bird baths, chicken yards, domestic livestock, fencing and supplementary food.
- Substrate.

The habitat heterogeneity of the local matrix surrounding each bird survey plot was quantified by visually estimating the percentage of the surrounding area (to a distance of 100 m from the edge of the survey plot) covered by: forest (exurban and / or wildland), modified forest, trees (irrespective of understorey), and paddocks. Percentage covers for these surrounding habitats were estimated into the categories: 0 -5 %, 5 – 10 %, 10 – 25 %, 25 – 50 %, 50 – 75 %, and 75 – 100 %. Within the same local matrix, less common habitats types were quantified merely by their presence / absence. These habitats were: gardens, dams, saltmarsh (tidal flats), and

coastal habitat, which was mostly comprised of dune grassland, but also included beaches, rocks, and the ocean.

Other local and landscape variables were derived from topographic maps and aerial photos. These were: the distance to the nearest house; the number of houses with a 200 m radius from the centre of the site; the size of the forest patch in which forest sites were located; the size of the paddock patch in which paddocks were located; the distance to a wildland remnant > 100 ha in area.

Data analysis

Community ordination, classification and comparison

Differences in the bird species assemblages of habitats within and between regions were tested by analyses of similarity (ANOSIM) using Bray-Curtis similarity and 10 000 permutations in DECODA (Minchin, 2001). Communities were considered to be discrete if P = < 0.05 in a pairwise comparison, with r indicating the level of separation. To support the ANOSIM tests, sites were also ordinated using non-metric multi-dimensional scaling with the default options in DECODA. The ordination solution with the smallest number of dimensions and a stress value < 0.20 was accepted. This technique produces the least distortions for data sets with large numbers of zeros (Minchin, 1987). Mean levels of similarity between sites within habitats and dissimilarity between habitats within and between regions, and the bird species that contributed most to the levels of similarity and dissimilarity, were identified using the SIMPER (similarity percentage) test in PRIMER (Clarke and

Gorley, 2000). All of the above tests used untransformed bird frequency of occurrence (per site) data.

Independent variables

All data derived from the assessments of bird survey site vegetation and locations were converted to binomial class variables for analysis. The only exception to this was plant species richness, which remained continuous. Binary variables enabled the use of broad habitat categories that could be assessed by eye in the field. In many cases the distribution of data for independent variables that were recorded as continuous were heaped into a small number of classes anyway, meaning that data classes had to be conflated in order to increase sample size. Each independent variable is listed and defined in Appendix A.

Unfortunately, as much of the data relating to exurban management techniques was attained from the print survey (Chapter 5), it could only be applied to property level analyses, rather than the site level analyses in this chapter. This includes variables relating to domestic predator activity and management. Domestic predators were recorded within bird survey sites during observations, but quantitative measures of predator presence could not be included in analyses, because often the cats and dogs were only in the site area because they followed the observer there.

Response variable relationships

Pearson's Chi-square contingency test was used to test variation in bird species frequencies of occurrence between habitat types. To test for correlations between

plot attributes and the likelihood of individual bird species being recorded at a given site in at least one of the seven surveys, Pearson's Chi-square or Fisher's Exact Probability Test were used for attributes treated as class variables and One-Way ANOVA for continuous variables. In all cases a level of $P < 0.05$ was taken to denote a significant relationship.

Response variable predictors

Correlations between plot attributes and individual bird species abundances, as well as total, native and exotic bird abundance, and total, native and exotic bird species richness were tested using One-Way ANOVA for class variables and Pearson's Product Moment Correlation for continuous variables. As an exploratory process, each variable significantly correlated with any given bird species or bird group was entered into a best subsets regression analysis in Minitab. A best subsets analysis produces regressions models using between 1 and *x* independent variables (with *x* equalling the total number of independent variables entered into the best subsets analysis) and indicates the two most explanatory regression models possible using each number of independent variables between 1 and *x* (*i.e.* the total number of regression models that result from each best subset analysis = 2*x*). These models were tested using general linear modelling, with continuous variables as covariates. The model with the highest adjusted R^2 was accepted if all components of the model were significant and the residuals had a normal (or at least approximately normal) distribution, as shown in histogram. If this was not the case, the next most explanatory model was examined, and so on, until one, or no, multi-variate model

satisfied these requirements (*i.e.* univariate models were considered redundant in light of other univariate analyses, and were thus disregarded).

Correlated independent variables

The relationships between all independent variables were explored using Pearson's x^2, Fishers Exact Probability Test, and One-Way ANOVA (Appendix B, Appendix C).

Results

Habitat variation

Canopy cover, understorey density, grass, forb and graminoid cover, and plant species richness, best defined the habitat types in each region (Figure 6, Figure 7).

Avifaunal variation

A total of 64 bird species were recorded within wildland and exurban sites (Appendix D and Appendix E). Thirty-six species were recorded in wildland sites and 61 in exurban sites. Only three species were recorded exclusively in wildland sites, the swift parrot, blue-wing parrot and scrubtit, but the blue-winged parrot was recorded nesting in exurbia (Appendix F). Excluding species that were recorded in less than ten surveys in total, not a single species was recorded exclusively in wildlands, while ten species were recorded only in exurbia. Six of these ten exurban specialists were natives: masked lapwing, Tasmanian native-hen, forest raven, Australian magpie, eastern rosella, and noisy miner. The latter three edge species were recorded exclusively in South Arm. Exurban specialists and / or members of the edge assemblage comprised eight of the 18 native species recorded nesting in exurbia.

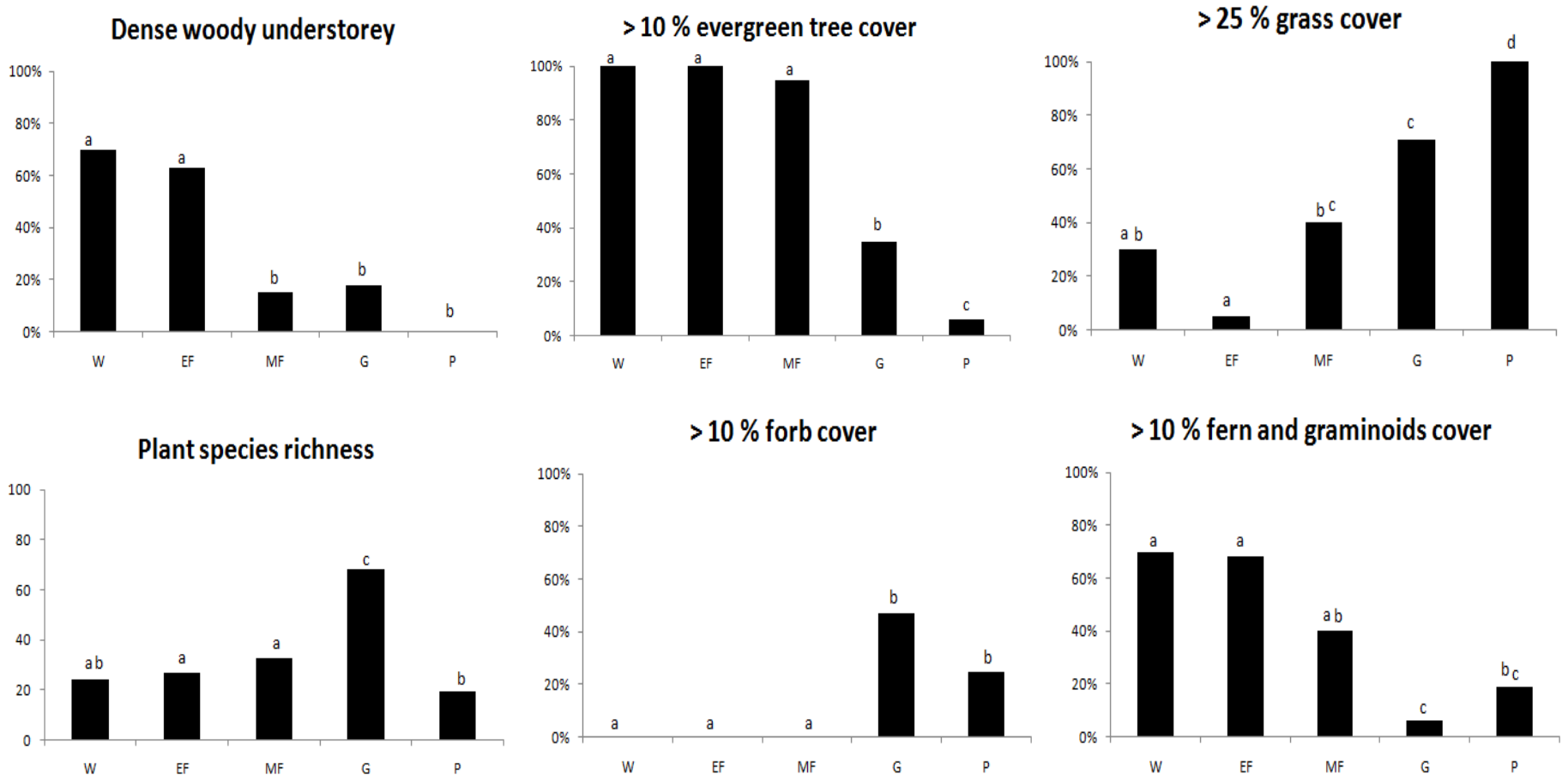

Figure 6: Mean plot plant species richness and the percentage of wildland (W), exurban forest (EF), modified forest (MF), garden (G) and paddock (P) plots in Kingborough that met the conditions of five contrasting class variables. Shared letters within each chart indicate no significant difference.

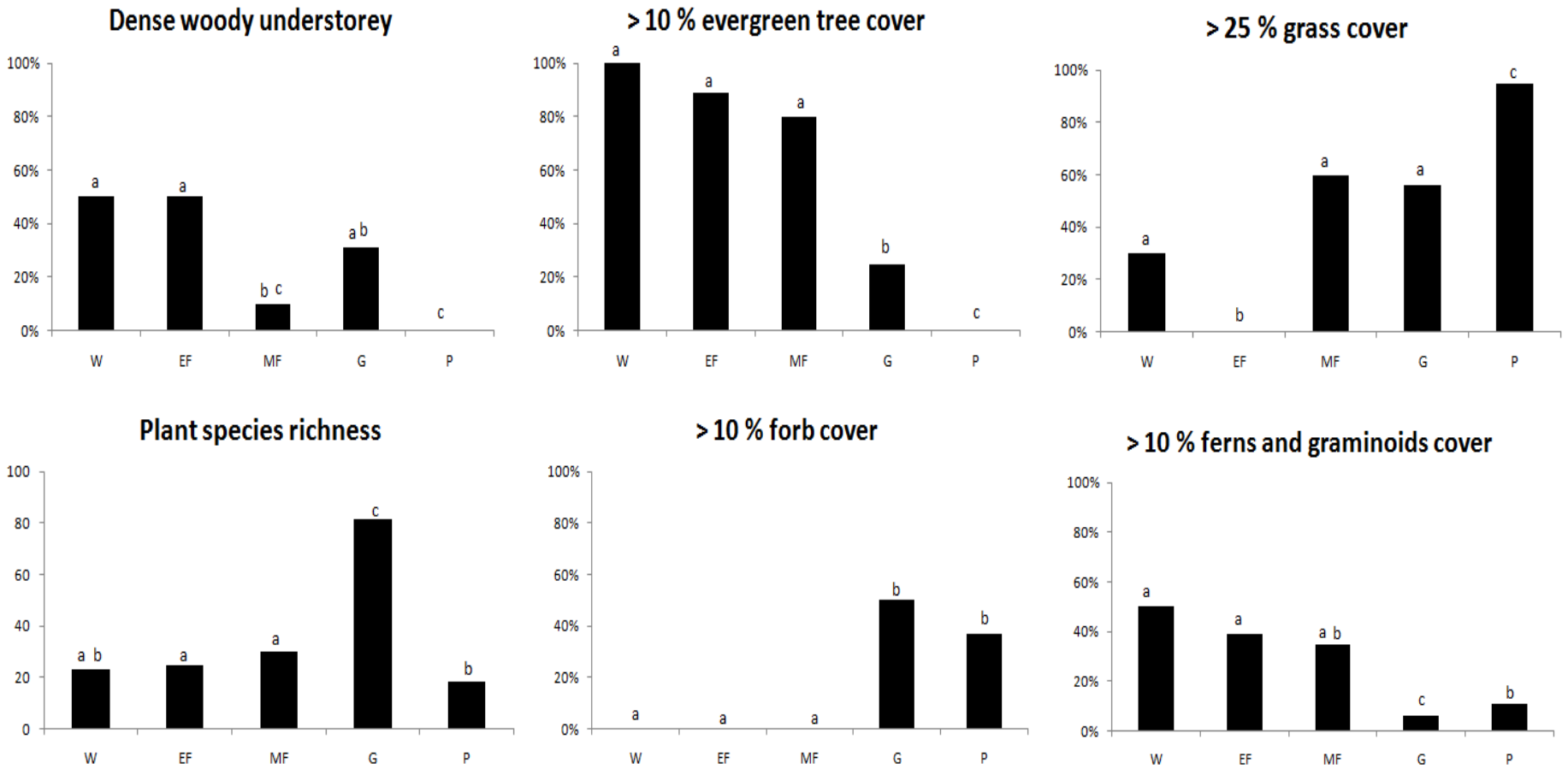

Figure 7: Mean plot plant species richness and the percentage of wildland (W), exurban forest (EF), modified forest (MF), garden (G) and paddock (P) plots in South Arm that met the conditions of five contrasting class variables. Shared letters within each chart indicate no significant difference.

The four exotic exurban specialists were the European goldfinch, common blackbird, common starling and house sparrow. The latter three were all recorded nesting in exurbia. Exotic species were not recorded nesting in native plants or wildlands. More nests were located in gardens than any other exurban habitat. Tasmanian native trees were the most common nest sites within exurbia and overall.

Overall, the bird species assemblages that inhabited each exurban region did not significantly differ from the wildland assemblages, even with the inclusion of exotic species and despite the presence of edge species (Table 1). However, such a broad comparison is misleading, as exurban habitats were not sampled in direct proportion to their total exurban distribution.

Table 1: Analysis of similarity of the bird species assemblages of exurban regions and representative wildlands

	All species		Native species only	
	R	P	R	P
Wildlands – Exurban Kingborough	0.0907	0.1700	0.0797	0.2026
Wildlands – Exurban South Arm	0.0596	0.2007	0.0609	0.2056

When treated singly, gardens and paddocks harboured bird communities that were discrete from those in wildlands (Table 2). However, the differences between the bird species communities in wildlands and exurban and modified forests remained not significant, but only marginally so for modified forests. Thus, wildland assemblages can inhabit an urban matrix, but forest disturbance must be minimal.

Within each region, the bird species assemblages of modified forest and exurban forest did not significantly differ, while the assemblages within gardens and paddocks were distinct (Table 3). The only exception to this was the native species assemblages within South Arm gardens and modified forests, which were not

significantly different, suggesting a level of homogenisation due to the presence of noisy miners.

Table 2: Analysis of similarity between the bird species assemblages of wildlands and individual exurban habitats within each region

	All species		Native species only	
Region and paired habitats	R	P	R	P
Kingborough				
Wildlands – Exurban forest	0.0049	0.4350	-0.0015	0.4648
Wildlands – Modified forest	0.1535	0.0551	0.1465	0.0587
Wildlands – Gardens	0.5267	0.0000	0.4908	0.0000
Wildlands – Paddocks	0.4170	0.0000	0.3636	0.0000
South Arm				
Wildlands – Exurban forest	0.0909	0.1156	0.0918	0.1142
Wildlands – Modified forest	0.1114	0.0822	0.1120	0.0755
Wildlands – Gardens	0.3916	0.0001	0.3182	0.0018
Wildlands – Paddocks	0.3388	0.0004	0.3230	0.0004

Table 3: Analysis of similarity between the bird species assemblages of exurban habitats within a region

	All species		Native species only	
Region and paired habitats	R	P	R	P
Kingborough				
Exurban forest – Modified forest	0.0098	0.3434	0.0035	0.4172
Exurban forest – Gardens	0.3370	0.0000	0.2958	0.0000
Exurban forest – Paddocks	0.4595	0.0000	0.4416	0.0000
Modified forest – Gardens	0.1362	0.0029	0.1295	0.0029
Modified forest – Paddocks	0.3526	0.0000	0.3503	0.0000
Gardens – Paddocks	0.3788	0.0000	0.3847	0.0000
South Arm				
Exurban forest – Modified forest	0.0084	0.3052	0.0065	0.3304
Exurban forest – Gardens	0.2659	0.0006	0.2179	0.0020
Exurban forest – Paddocks	0.3398	0.0001	0.3250	0.0000
Modified forest – Gardens	0.0917	0.0421	0.0505	0.1083
Modified forest – Paddocks	0.2410	0.0000	0.2360	0.0004
Gardens – Paddocks	0.1515	0.0063	0.1247	0.0117

There were no significant regional similarities in the bird communities within any given habitat type (Table 4). Thus, the study area on the whole, exurbia and wildlands inclusive, can be considered to be comprised of three distinct bird species

assemblages, forest birds, which inhabit wildlands, exurban forest and modified forest, garden birds, and paddock birds, with the composition of each also varying between regions (Figure 8).

Table 4: Analysis of similarity between the bird species assemblages of individual habitats between regions

	All species		Native species only	
	R	P	R	P
Wildlands	0.1179	0.0366	0.1179	0.0366
Exurban forest	0.1964	0.0003	0.1926	0.0001
Modified forest	0.1831	0.0004	0.1797	0.0001
Gardens	0.2877	0.0000	0.3126	0.0000
Paddocks	0.0886	0.0350	0.0843	0.0424

Regional dissimilarity in the bird species composition of habitats was highest in paddocks, lower in forests, and lowest in gardens (Table 5). The superb fairy-wren was the only species to make a large contribution (> 5 %) to the total regional dissimilarity within every habitat type. In all habitats it was more frequently recorded in the Kingborough region. Brown thornbills and New Holland honeyeaters contributed to > 5 % of the regional dissimilarity in two habitat types each, and were uniformly more frequently recorded in Kingborough. Noisy miners, scarlet robins and little wattlebirds made large contributions to regional dissimilarities on account of their relatively high frequencies of occurrence in South Arm.

Noisy miners did not dichotomise South Arm and wildland assemblages as expected, or homogenise South Arm communities as much as expected, because they were not distributed uniformly across the region. Residential perforations did not create points of invasion for miners, which were largely restricted to small forest remnants and forests on the edge of historically cleared land (Figure 9). If only sites

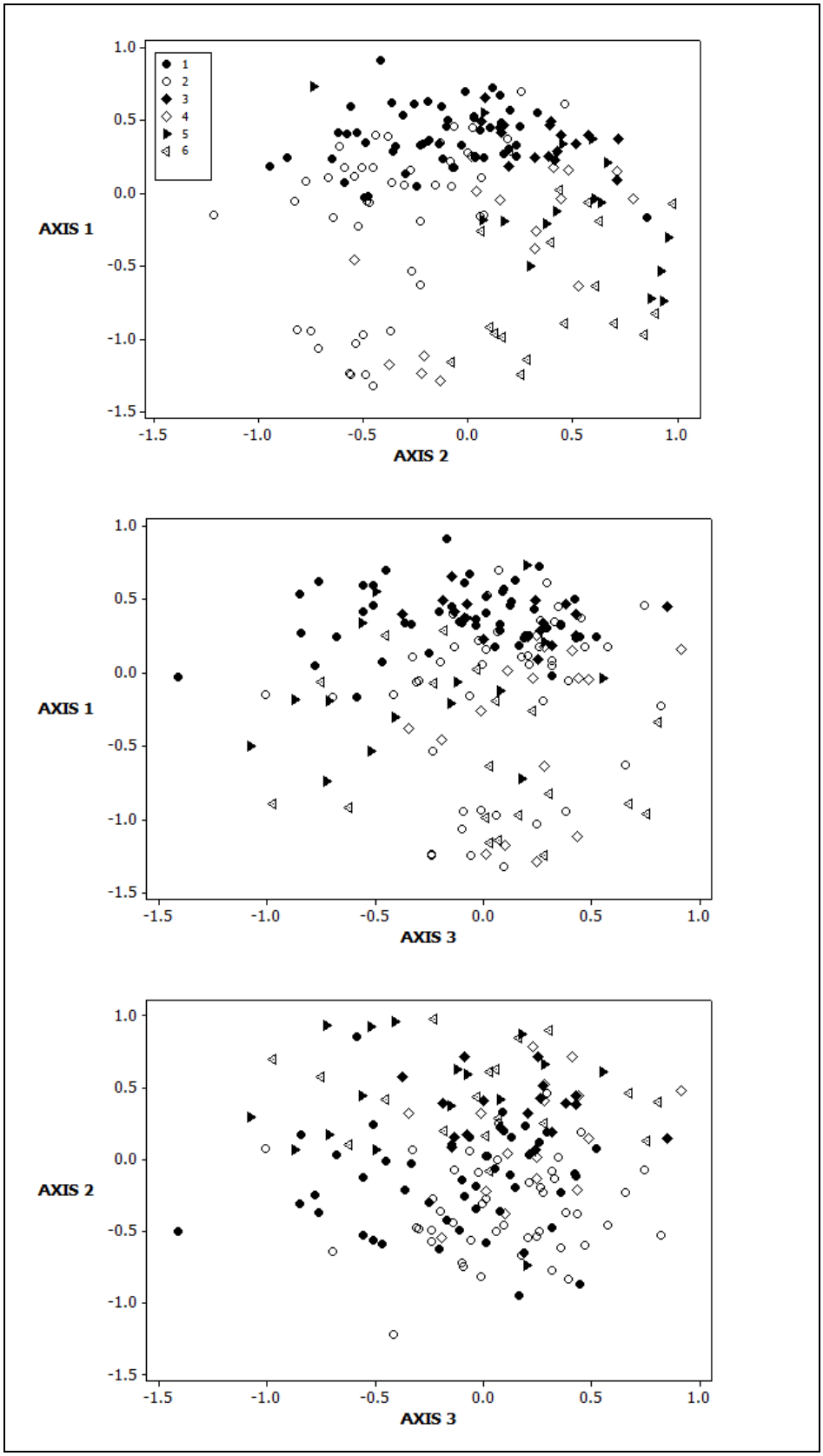

Figure 8: Three-dimensional distribution of the bird species assemblages of habitats based on frequency of occurrence by site. 1 = Kingborough forests; 2 = South Arm forests; 3 = Kingborough gardens; 4 = South Arm gardens; 5 = Kingborough paddocks; 6 = South Arm paddocks.

Table 5: The percentage contribution of species that contribute to the top 40% of mean intersite similarity within habitats and mean dissimilarity between paired habitats between and within regions. Total refers to the overall level of similarity or dissimilarity.

	Intersite similarity (% contribution) [a]						Inter-regional habitat dissimilarity (% contribution) [a b]			Regional interhabitat dissimilarity (% contribution) [a b]					
	KF	KG	KP	SF	SG	SP	KFvSF	KGvSG	KPvSP	KFvKG	KFvKP	KGvKP	SFvSG	SFvSP	SGvSP
Brown thornbill	16.42		13.54				5.89 $_{K}$		5.78 $_{K}$	5.29 $_{F}$	6.84 $_{F}$	4.72 $_{G}$			
Black-headed honeyeater							4.13 $_{S}$								
Common blackbird								5.42 $_{K}$		5.39 $_{G}$		6.07 $_{G}$			
Crescent honeyeater											4.26 $_{F}$				
Grey fantail	11.56						5.02 $_{K}$			4.32 $_{F}$	5.59 $_{F}$				
House sparrow								7.18 $_{S}$		5.09 $_{G}$		6.24 $_{G}$	6.28 $_{G}$		7.66 $_{G}$
Little wattle bird					11.91			6.24 $_{S}$					7.28 $_{G}$		8.73 $_{G}$
Masked lapwing									8.34 $_{K}$		3.86 $_{P}$				
New Holland honeyeater							5.93 $_{K}$	9.40 $_{K}$		10.05 $_{G}$	6.49 $_{F}$	12.93 $_{G}$	5.91 $_{G}$		5.48 $_{G}$

	Intersite similarity (% contribution) [a]						Inter-regional habitat dissimilarity (% contribution) [a b]			Regional interhabitat dissimilarity (% contribution) [a b]					
	KF	KG	KP	SF	SG	SP	KFvSF	KGvSG	KPvSP	KFvKG	KFvKP	KGvKP	SFvSG	SFvSP	SGvSP
Noisy miner				8.32	16.64		5.50 $_{S}$	5.05 $_{S}$					8.11 $_{G}$	8.37 $_{F}$	8.17 $_{G}$
Scarlet robin							4.00 $_{S}$		5.65 $_{S}$					5.05 $_{F}$	
Spotted pardalote				9.75										4.51 $_{F}$	
Striated pardalote				10.95										4.70 $_{F}$	
Superb fairy-wren	11.02	30.04	34.23		15.02		5.69 $_{K}$	9.69 $_{K}$	12.66 $_{K}$	10.62 $_{G}$	7.83 $_{P}$	12.32 $_{G}$	6.98 $_{G}$	6.42 $_{P}$	8.83 $_{G}$
Welcome swallow						32.29			8.02 $_{S}$					5.11 $_{P}$	4.82 $_{G}$
Yellow-throated honeyeater	9.76			17.00			6.66 $_{S}$				5.51 $_{F}$		6.34 $_{F}$	7.82 $_{F}$	
Total	30.14	41..91	23.44	24.27	25.98	17.74	77.06	74.48	82.02	70.96	82.91	77.35	81.29	87.81	83.58

[a] K = Kingborough; S = South Arm; F = Forests; G = Gardens; P = Paddocks

[b] Adjacent subscripts refer to the habitat or region in which the species was more frequent, using the same abbreviations as above

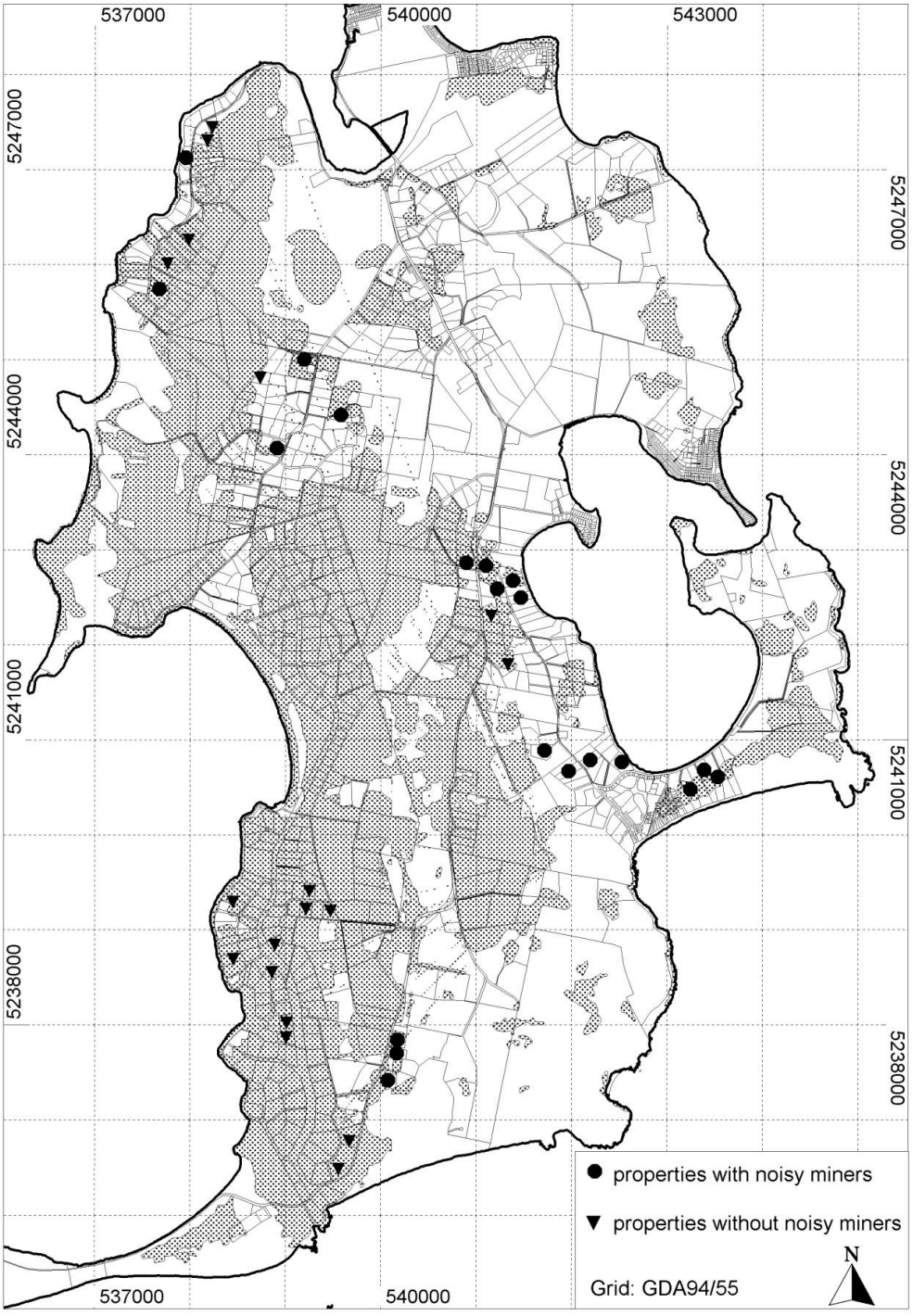

Figure 9: The distribution of noisy miners at South Arm sites in relation to forest (shaded) and house distribution. Properties with paddock sites only are excluded from miner distribution.

in which miners were present are considered, then all South Arm exurban habitats harbour bird assemblages discrete from the wildlands assemblage (Table 6). The presence of noisy miners also influences the differences between the bird communities of different exurban habitats. Within their exurban territory noisy miners homogenised bird species assemblages across all habitats except paddocks (Table 6, Figure 10). Sites in which miners were recorded frequently (> 14 % frequency of occurrence) had strikingly similar bird species compositions (Figure 11).

Table 6: Analysis of similarity between the bird species assemblages of wildlands and South Arm sites with noisy miners, as well as analysis of similarity between South Arm habitat sites with miners

	All species	
Region and paired habitats	R	P
South Arm		
Wildlands – Exurban forest	0.8941	0.0009
Wildlands – Modified forest	0.6498	0.0000
Wildlands – Gardens	0.5662	0.0000
Wildlands – Paddocks	0.8350	0.0001
Exurban forest – Modified forest	-0.1362	0.7734
Exurban forest – Gardens	0.2025	0.0838
Exurban forest – Paddocks	0.6726	0.0049
Modified forest – Gardens	0.0484	0.2233
Modified forest – Paddocks	0.3816	0.0048
Gardens – Paddocks	0.2525	0.0276

Despite regional bird community dissimilarity, there were similar regional patterns of bird species richness and abundance across habitats, even with the inclusion of miner sites (Figure 12). In each region, total species richness was highest in gardens, but not significantly higher than in forests. Native species richness peaked in forests, but was not significantly higher than in gardens. Exotic species richness peaked in gardens, but was not significantly higher than in paddocks. Total bird abundance was significantly higher in gardens than either forests or paddocks.

Native bird abundance also peaked in gardens, but was not significantly higher than in native bird abundance in forests.

In each region, levels of intersite similarity within habitats were highest in gardens, lower in forests, and lowest in paddocks (Table 5). In terms of regional interhabitat dissimilarity, paddocks and forests were more dissimilar to each other than forests and gardens, or gardens and paddocks (Table 5). Forests and gardens were less dissimilar than any other pair of habitats. Levels of intersite similarity within habitats, and interhabitat similarity within a region, were uniformly lower in South Arm, due to the contrast between sites with and without noisy miners in that region (Table 5). Abundant and widely distributed species such as the superb fairy-wren made large contributions to the overall levels of intersite similarity, and habitat dissimilarities. However, species that made large similarity contributions to only one habitat type characterise habitats best (Table 5). Kingborough forests were thus characterised by high frequencies of crescent honeyeaters, grey fantails and yellow-throated honeyeaters. Kingborough gardens were typified by high frequencies of common blackbirds, silvereyes and New Holland honeyeaters, and Kingborough paddocks by the presence of masked lapwings.

Despite the regional dominance of noisy miners, South Arm forests on the whole typically had a number of small native birds, such as brown thornbills, scarlet robins, striated pardalotes, spotted pardalotes, and yellow-throated honeyeaters; however, only the latter three contributed at least as much as the noisy miner to the overall intersite similarity within South Arm forests (Table 5).

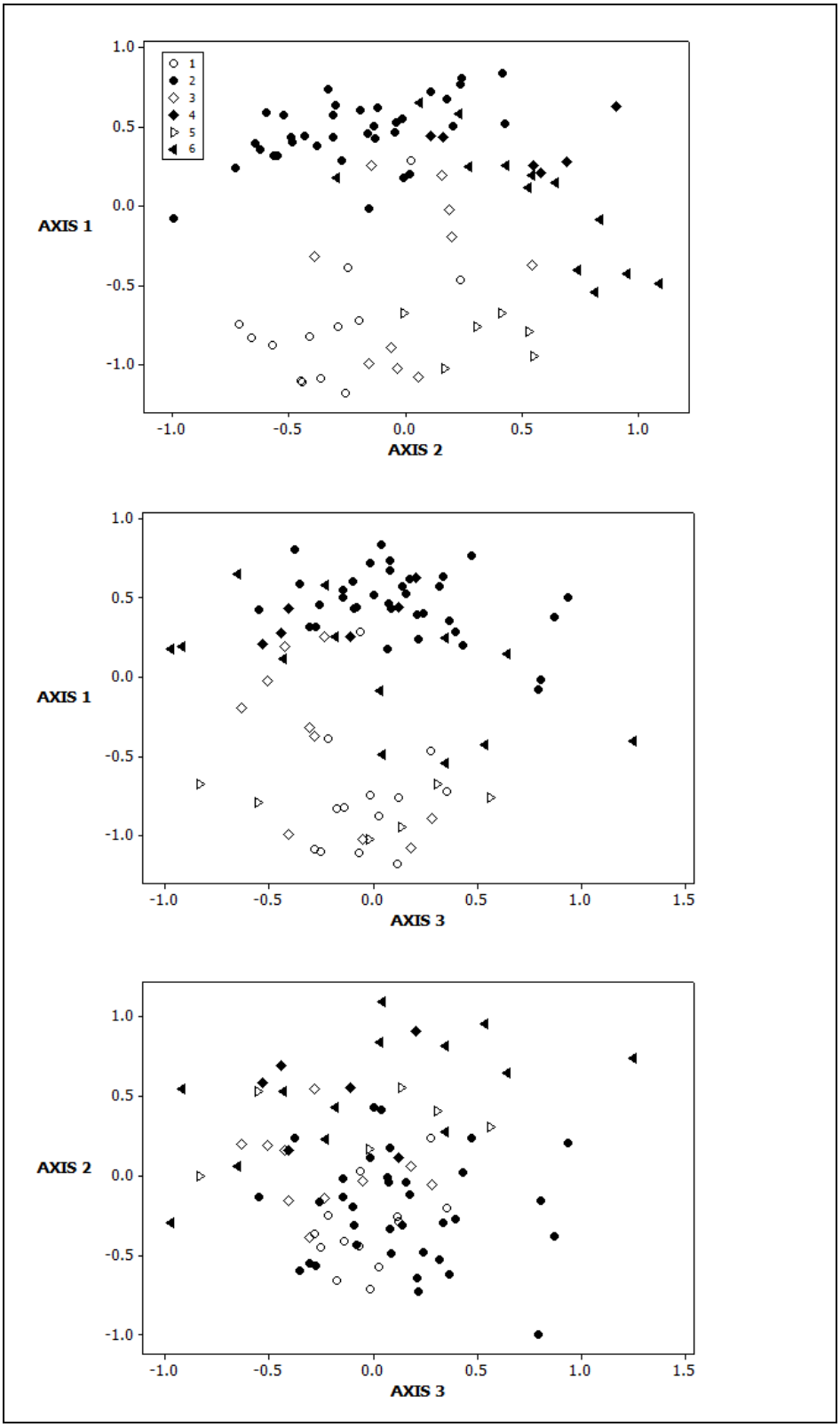

Figure 10: Three-dimensional distribution of the bird species assemblages of South Arm habitats with and without miners. 1 = forests with miners; 2 = forests without miners; 3 = gardens with miners; 4 = gardens without miners; 5 = paddocks with miners; 6 = paddocks without miners.

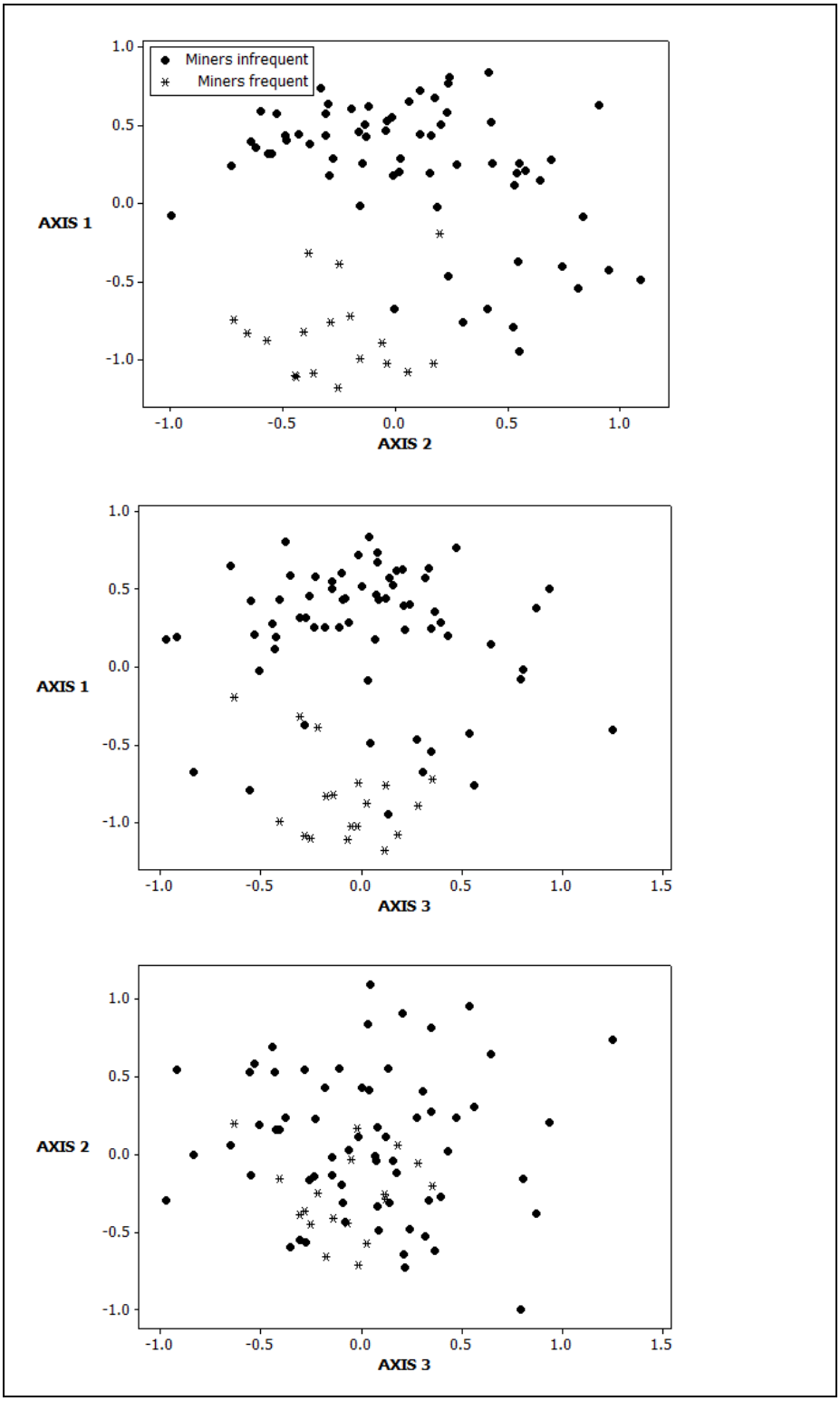

Figure 11: Three-dimensional distribution of the bird species assemblages of South Arm sites, sorted by frequency of occurrence of noisy miners. Frequent = > 14 % frequency of occurrence.

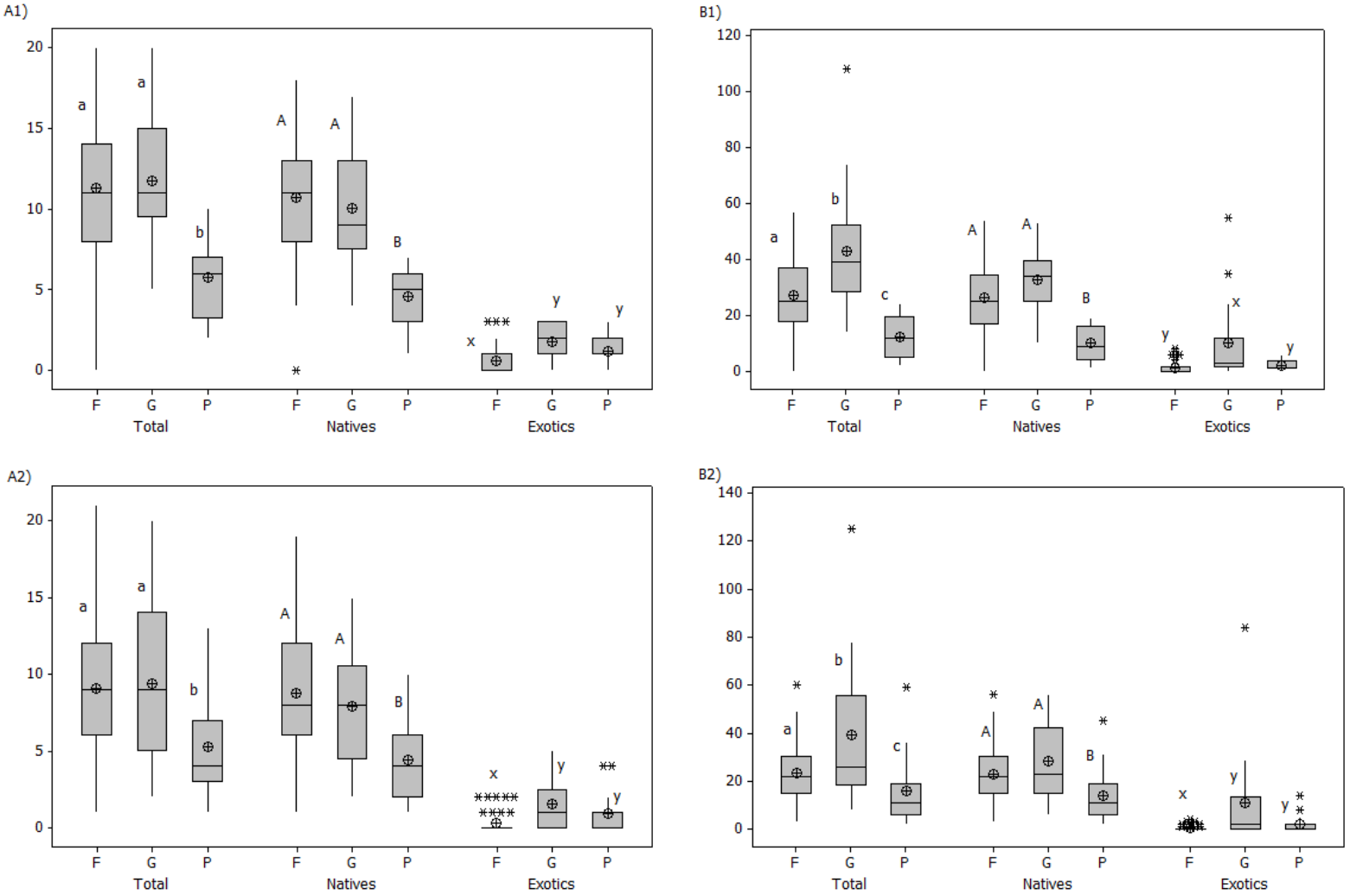

Figure 12: Mean site A) species richness, and B) abundance for forest (F), garden (G) and paddock (P) habitats in 1) Kingborough and 2) South Arm. Crosshairs indicate mean. Shared letters indicate that means values do not significantly differ. Boxes contain 25 % of the observations on either side of the median, which is the middle horizontal line. Whiskers indicate the range. Asterisks denote outliers.

Thus, bird species can be classified by the exurban habitats that they most frequent. Several species differed significantly in their frequencies of occurrence between habitats within regions (Table 7, Table 8). Some species displayed the same preference in each region, making them classic habitat specialists, and some species displayed a significant habitat preference in one region only, making them regional specialists. Species that displayed significant habitat preferences are thus classified into three classes: forest specialists, garden specialists, and paddock specialists, and each class has a subset of regional specialists (Table 9).

Table 7: Species that differed significantly in their percentage frequencies of occurrence between Kingborough habitats. Bold values indicate the habitat in which each species had the highest percentage frequency of occurrence.

	Forest	Garden	Paddock	x^2	*P*
Black-headed honeyeater	**11.08**	5.88	0.89	12.808	0.002
Brown thornbill	**22.74**	15.97	8.04	12.749	0.002
Common blackbird	7.00	**25.21**	6.25	33.663	0.000
Crescent honeyeater	12.83	**15.13**	0.00	17.335	0.000
Eastern spinebill	8.45	**12.61**	0.89	11.401	0.003
European goldfinch	2.62	**8.40**	1.79	9.757	0.008
Golden whistler	**5.54**	2.52	0.00	7.730	0.021
Green rosella	5.83	**9.24**	0.89	7.750	0.021
Grey fantail	**18.95**	13.45	3.57	16.050	0.000
House sparrow	0.58	**23.53**	8.04	73.795	0.000
Masked lapwing	0.58	0.00	**8.93**	31.934	0.000
New Holland honeyeater	17.20	**47.90**	10.71	58.830	0.000
Satin flycatcher	2.92	0.00	0.00	6.854	0.032
Silvereye	9.62	**15.97**	1.79	13.659	0.001
Spotted pardalote	**7.00**	4.20	0.89	6.670	0.036
Striated pardalote	**8.45**	2.52	0.00	14.125	0.001
Strong-billed honeyeater	**6.41**	4.20	0.00	7.833	0.020
Superb fairy-wren	20.41	**57.14**	21.43	62.023	0.000
Tasmanian scrubwren	**9.91**	1.68	0.89	17.043	0.000
Tasmanian thornbill	**7.29**	5.04	0.00	8.817	0.012
Welcome swallow	3.50	**15.13**	8.04	19.200	0.000
Yellow-rumped thornbill	0.29	1.68	**3.57**	7.805	0.020
Yellow-throated honeyeater	**16.33**	11.76	3.57	12.402	0.002

Table 8: Species that differed significantly in their percentage frequencies of occurrence between South Arm habitats. Bold values indicate the habitat in which each species peaked in frequency of occurrence.

	Forest	Garden	Paddock	x^2	*P*
Australian magpie	2.68	**7.14**	1.50	6.994	0.030
Black-headed honeyeater	**11.61**	3.57	0.00	20.940	0.000
Common blackbird	0.01	**16.96**	0.75	66.140	0.000
Common greenfinch	0.00	**3.57**	2.26	7.610	0.022
Common starling	0.60	**8.04**	3.76	18.016	0.000
Eastern rosella	3.27	**5.36**	0.00	6.483	0.039
Golden whistler	**4.17**	0.000	1.50	6.452	0.040
Green rosella	7.14	**11.61**	0.00	14.671	0.001
Grey fantail	**10.42**	3.57	4.51	8.033	0.018
House sparrow	1.19	**29.46**	5.26	97.249	0.000
Little wattlebird	3.57	**30.36**	3.01	83.499	0.000
Masked lapwing	0.00	0.89	**6.77**	26.357	0.000
New Holland honeyeater	13.10	**18.75**	1.50	19.635	0.000
Noisy miner	14.88	**17.86**	5.26	10.225	0.006
Spotted pardalote	**13.10**	7.14	0.75	18.167	0.000
Striated pardalote	**12.20**	7.14	0.75	16.887	0.000
Superb fairy-wren	12.50	**31.25**	13.53	23.363	0.000
Tasmanian native-hen	0.00	4.46	**7.52**	23.372	0.000
Welcome swallow	4.46	**12.78**	4.49	12.906	0.002
Yellow-throated honeyeater	**21.73**	8.93	3.01	30.983	0.000

Eleven species were forest or regional forest specialists. All of these forest species were small native insectivores. Sixteen species were garden or regional garden specialists. Garden species were also mostly small, but included five medium or large species. Garden species comprised a greater mix of feeding guilds. Only three of the garden species are primarily insectivores. Four are omnivores, four are nectivores, and five are granivores. Some species were too rare to be analysed for variation in habitat use, but can tentatively be considered habitat specialists as they were restricted to a single habitat type (Table 10). Fifty-percent of forest restricted species were insectivores and 28.5 % were medium to large carnivores.

Table 9: Exurban habitat specialists.

	Habitat association/ classification	Diet	Nest	Size (S: < 50 g; M: 50-200 g; L: > 200 g)
Black-headed honeyeater	Forest	Insectivore	Open cup	Small
Golden whistler	Forest	Insectivore	Open cup	Small
Grey fantail	Forest	Insectivore	Open cup	Small
Spotted pardalote	Forest	Insectivore	Chamber	Small
Striated pardalote	Forest	Insectivore	Cavity/chamber	Small
Yellow-throated honeyeater	Forest	Insectivore	Open cup	Small
Brown thornbill	Regional forest	Insectivore	Dome	Small
Satin flycatcher	Regional forest	Insectivore	Open cup	Small
Strong-billed honeyeater	Regional forest	Insectivore	Open cup	Small
Tasmanian scrubwren	Regional forest	Insectivore	Dome	Small
Tasmanian thornbill	Regional forest	Insectivore	Dome	Small
Common blackbird	Garden	Omnivore	Open cup	Medium
Green rosella	Garden	Granivore	Cavity	Medium
House sparrow	Garden	Granivore	Dome/cavity	Small
New-Holland honeyeater	Garden	Nectivore	Open cup	Small
Superb fairy-wren	Garden	Insectivore	Dome	Small
Welcome swallow	Garden	Insectivore	Open cup	Small
Australian magpie	Regional garden	Omnivore	Open cup/ bowl	Large
Common greenfinch	Regional garden	Granivore	Open cup	Small
Common starling	Regional garden	Omnivore	Cavity	Medium
Crescent honeyeater	Regional garden	Nectivore	Open cup	Small
Eastern rosella	Regional garden	Granivore	Cavity	Medium
Eastern spinebill	Regional garden	Nectivore	Open cup	Small
European goldfinch	Regional garden	Granivore	Open cup	Small
Little wattlebird	Regional garden	Nectivore	Open cup	Medium
Noisy miner	Regional garden	Insectivore	Open cup	Medium
Silvereye	Regional garden	Omnivore	Open cup	Small
Masked lapwing	Paddock	Insectivore	Ground	Large
Tasmanian native-hen	Regional paddock	Granivore/herbivore	Ground/ riparian	Large
Yellow-rumped thornbill	Regional paddock	Insectivore	Dome	Small

Eighteen species not restricted to a single habitat type could not be classified as habitat specialists. In most cases, this was because the species was recorded too infrequently for robust analysis. Thus, they are not definitively considered habitat generalists. Two species, tree martins and scarlet robins, were quite abundant, but displayed inconsistent habitat associations within and between regions (Appendix D).

Table 10: Species recorded exclusively in one habitat type

	Habitat preference	Diet	Nest	Size (S: < 50 g; M: 50-200 g; L: > 200 g)
Kookaburra	Forest	Carnivore	Cavity	Large
Brown goshawk	Forest	Carnivore	Bowl/platform	Large
Collared sparrowhawk	Forest	Carnivore	Bowl/platform	Medium
Grey goshawk	Forest	Carnivore	Bowl/platform	Large
Tawny frogmouth	Forest	Insectivore	Open cup/platform	Large
Fan-tailed cuckoo	Forest	Insectivore	Parasitic	Medium
Horsfield's bronze-cuckoo	Forest	Insectivore	Parasitic	Small
Scrubtit	Forest	Insectivore	Dome	Small
Black-faced cuckoo-shrike	Forest	Insectivore	Open cup/platform	Medium
Satin flycatcher	Forest	Insectivore	Open cup	Small
Forty-spotted pardalote	Forest	Insectivore	Cavity	Small
Blue-winged parrot	Forest	Granivore	Cavity	Medium
Swift parrot	Forest	Nectivore	Cavity	Medium
Musk lorikeet	Forest	Nectivore	Cavity	Medium
Striated fieldwren	Gardens	Insectivore	Dome	Small
Wood duck	Paddocks	Herbivore	Cavity	Large
Brown quail	Paddocks	Granivore/insectivore	Ground	Medium

All the potential habitat generalists and the two species with inconsistent exurban distributions are potentially responding to factors other than broad habitat types. Thus, to aid in the interpretation of the distribution of these species, the likelihood of them being recorded at any given exurban site, and their total site abundance, were each tested against plot variables relating to site, local, and landscape variation.

Ten of these species were significantly correlated with at least one plot variable in at least one region, and two species were sufficiently abundant for predictive models to be derived for at least one region (Table 11, Table 12 and Table 13). Species correlations with plot variables were highly individualistic.

Table 11: Exurban plot characteristics significantly related to the occurrence of species in Kingborough sites. Degrees of freedom equal one in all cases. * F = Fisher's exact probability test.

	Pearson x^2	*P* value*	Variable influence (+/−)
Dusky robin			
Bird bath	5.708	0.017	+
Supplementary feeding	5.708	0.017	+
Grey currawong			
> 10 % fern and graminoid cover	4.124	0.042	−
Small tree(s)	4.383	0.036	+
Surrounding garden(s)	10.499	0.001	−
Grey shrike-thrush			
Chicken yard		0.041 [F]	+
Olive whistler			
> 10 % fern and graminoid cover	6.824	0.009	+
Scarlet robin			
> 10 % fern and graminoid cover	4.194	0.041	−
> 10 % surrounding tree cover	6.000	0.014	−
> 25 % grass cover	4.673	0.031	+
> 25 % forest surrounds	5.896	0.015	−
Fencing	4.448	0.035	+
Tree martin			
Surrounding garden(s)		0.042 [F]	−
Yellow wattlebird			
> 10 % evergreen tree cover	6.968	0.008	+
> 25 % grass cover	4.580	0.032	−
Dominant strata > 8 m	8.780	0.003	+

Table 12: Exurban site characteristics significantly related to the occurrence of species in South Arm sites. Degrees of freedom equal one in all cases. * F = Fisher's exact probability test.

	Pearson x^2	*P* value*	Variable influence (+/−)
Dusky robin			
> 10 % evergreen tree cover	4.365	0.037	+
> 10 % fern and graminoid cover	4.628	0.031	+
Coastal surrounds	4.998	0.025	−
Dominant strata > 8 m	4.435	0.035	+
Surrounding garden(s)	12.916	0.000	−
Forest raven			
> 10 % evergreen tree cover	6.719	0.010	+
> 25 % cover evergreen cover		0.048 [F]	+
Dominant strata > 8 m	5.192	0.023	+
Grey butcherbird			
> 25 % grass cover	5.699	0.017	+
> 25 % forest surrounds	6.021	0.014	−
> 25 % paddock surrounds	4.469	0.035	+
Bare ground		0.006 [F]	−
Mudstone	4.143	0.042	−
Sandy soils	4.143	0.042	+
Scarlet robin			
> 10 % surrounding tree cover	4.624	0.032	+
Maximum vegetation height > 8 m	4.232	0.040	+
Surrounding garden(s)	5.419	0.020	−
Tree martin			
> 10 % fern and graminoid cover	6.743	0.009	−
> 10 % small shrub cover	5.499	0.019	+
Dominant strata > 8 m	5.160	0.023	−
Fencing	4.204	0.040	+
Large shrub(s)	5.015	0.025	−
Non-equine stock	5.515	0.019	+

Table 13: Independent variables significantly correlated to the abundances of potential generalists within exurban sites, including the variables that comprise the predictive models and their predictive power.

1 = significantly singly, but does not appear in model; X = model component; * = most explanatory variable within model; +/- = variable exerts a positive/negative influence on species abundance.

	> 10 % EverTreeCover	Ferns and graminoids	>10% forb cover	> 10 % SurrTreeCover	> 25 % Forest surrounds	> 25 % EverTreeCover	> 25 % grass cover	Paddock Surrounds	Bare ground	Bird bath	Forest patch > 100 ha	Chicken yard	Dominant strata > 8 m	Equine stock	Fencing	Max Veg Height > 8 m	Mudstone	Non-equine stock	Paddock patch > 100 ha	Remnant proximity	Sandy soil	Small tree(s)	Stock	Supplementary feeding	Surrounding dam(s)	Surrounding garden(s)	Surr. Imperv. Surf.	Surrounding saltmarsh	R^2
Dusky robin – Kingborough																			1 -						1 -				
Flame robin – Kingborough																				1+									
Forest raven – South Arm	1 +					1 +																							
Grey butcherbird – South Arm					X -		1+	1+	X - *								1-				1+							1+	20.34
Grey currawong – Kingborough																						1 +				1 -	1 -		
Grey shrike-thrush – Kingborough											1 -																		
Olive whistler – Kingborough		1 +										1 +												1+					
Scarlet robin- Kingborough		1 -			1 -		1+								1+			1+					1+						
Scarlet robin – South Arm				1 +												X+*				X+						1 -			13.35
Tree martin – Kingborough										1 +		1 +												1+					
Tree martin – South Arm			1 +												1+														
Yellow wattlebird - Kingborough	1 +						1 -						1+																

All other species were also tested for correlations with plot variables (Appendix G and Appendix H), and predictive models were derived for many species (Appendix I, Appendix J, Appendix K and Appendix L). Not surprisingly, habitat specialists and habitat restricted species tended to be positively correlated with site variables that typified their preferred habitat. These tests also further demonstrated that noisy miner abundance peaked in areas without extensive forest surrounds and in small remnants.

Habitat specialists and restricted species were tested for sensitivity to human disturbance by exploring correlations between the cumulative species richness and abundance of each group of specialists and housing proximity and density of houses within a 200 m radius within only their preferred habitat types. *i.e.* forest specialist richness and abundance were tested against housing measures in forest sites only, to avoid correlations being confounded by shifts in species assemblages resulting from the invariable proximity of gardens to houses. No group of specialists displayed any significant correlation with housing proximity or density. The only exception to this was the abundance of forest specialists in South Arm, which was positively correlated with distance to nearest house (Pearson's = 0.361, P = 0.026). This, however, was confounded by the contrasting, but non-significant, negative correlation between noisy miner abundance and housing proximity (Pearson's = -0.209, P = 0.209). Thus when sites with miners were excluded, forest specialists displayed no significant correlation with housing proximity (Pearson's = 0.188, P = 0.367). Interestingly, correlations between house proximity and forest specialist richness (Pearson's = -0.280, P = 0.084), and housing density and paddocks specialist

richness (Pearson's = 0.487, P = 0.056) approached significance in Kingborough sites, suggesting that houses can have a slightly positive influence in some cases.

While it is evident that forests harbour a uniform bird assemblage regardless of an exurban or wildland location, there was small variation between the bird assemblages of wildlands and the two exurban forest habitats. Specifically, the modification of forest physiognomy leads to the invasion of exotic species (Figure 13), and, in direct comparison to the representative wildlands, some species had significantly different frequencies of occurrence in exurban forest habitats.

In Kingborough, two species, the tree martin and the eastern spinebill, significantly favoured wildlands in direct comparison to both exurban forest and modified forests (Table 14, Table 15). Tasmanian scrubwrens were recorded significantly more frequently in wildlands than modified forest, but did not significantly vary in commonness between exurban forest and wildlands. Four gardens specialists, common blackbird, European goldfinch, superb fairy-wren and welcome swallow, were significantly more frequently recorded in modified bushland than wildlands.

Table 14: Species that have significantly different percentage frequency of occurrence in wildlands and Kingborough exurban forest. Degrees of freedom equal one in all cases.

	Wildlands	Exurban forest	x^2	P value
Eastern spinebill	**18.57 %**	7.52 %	5.577	0.018
Scarlet robin	**7.14 %**	1.50 %	4.380	0.036
Tree martin	**8.57 %**	1.50 %	6.052	0.014

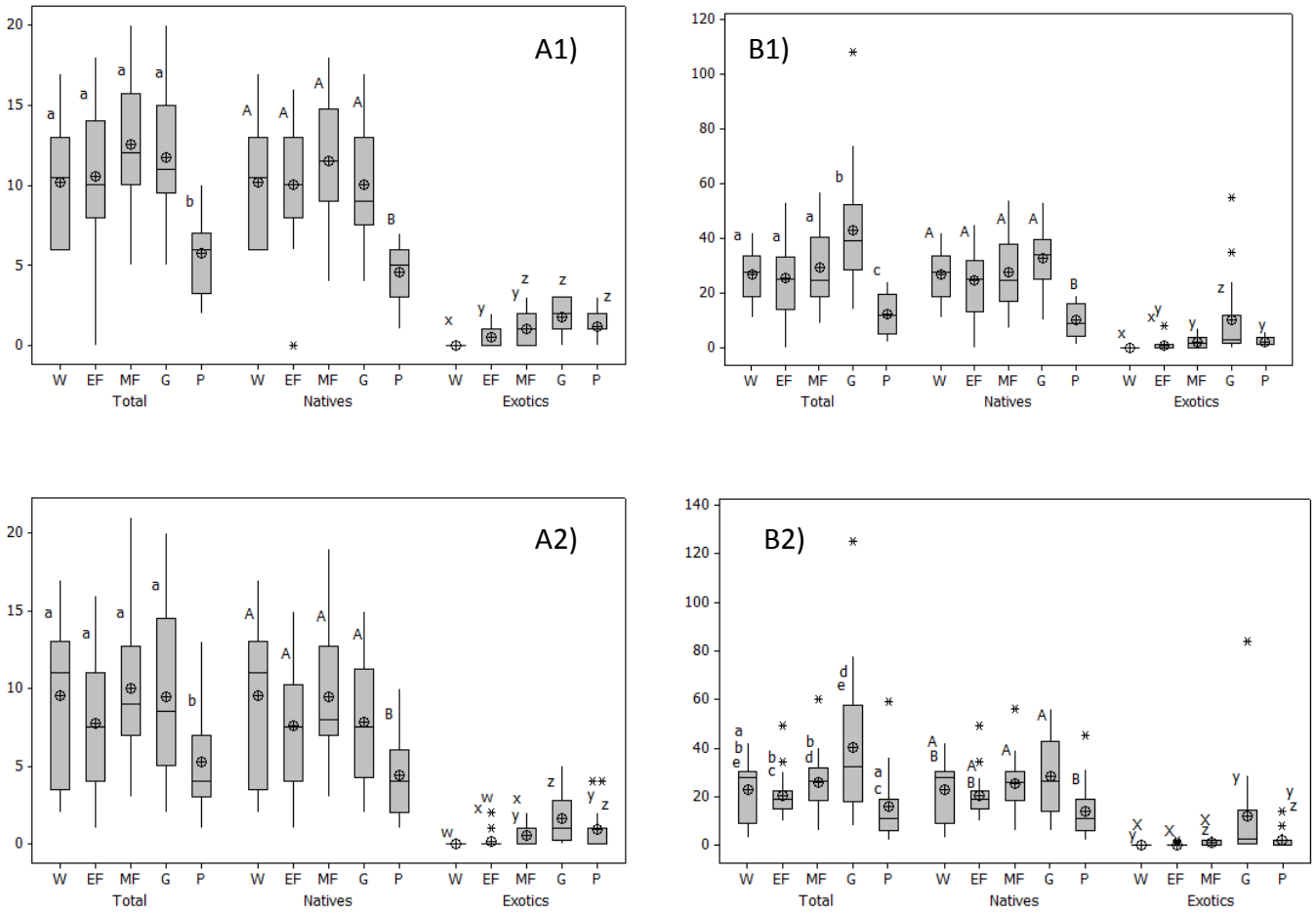

Figure 13: Mean site A) species richness, and B) abundance for wildlands (W), exurban forest (EF), modified forest (MF), garden (G) and paddock (P) habitats in 1) Kingborough and 2) South Arm. Crosshairs indicate mean. Shared letters indicate that means values do not significantly differ. Boxes contain 25 % of the observations on either side of the median, which is the middle horizontal line. Whiskers indicate the range. Asterisks denote outliers.

Table 15: Species that significantly differ in frequency of occurrence between wildlands and Kingborough exurban modified forest. Degrees of freedom equal one in all cases.

	Wildlands	Modified forest	x^2	P value
Common blackbird	0 %	**12.14 %**	9.249	0.002
Eastern spinebill	**18.57 %**	4.29 %	11.573	0.001
European goldfinch	0 %	**6.43 %**	4.701	0.030
Spotted pardalote	1.43 %	**9.29 %**	4.630	0.031
Superb fairy-wren	10.00 %	**29.29 %**	9.844	0.002
Tasmanian scrubwren	**14.29 %**	2.86 %	9.796	0.002
Tree martin	**8.57 %**	1.43 %	6.498	0.011
Welcome swallow	0 %	**7.14 %**	5.250	0.022

In South Arm, five native species were significantly less common in wildlands than they were in exurban forest (Table 16). One of these species, the satin flycatcher, also favoured wildlands compared to modified forest (Table 17). In contrast to the Kingborough area, where no species significantly favoured exurban forest over wildlands (Table 14), three species, noisy miner, spotted pardalote and yellow-throated honeyeater, did so in South Arm. The tree martin, the noisy miner, and two other classic edge species, the Australian magpie and the eastern rosella, were more frequently recorded in modified forest than wildlands.

Table 16 Species that significantly differ in frequency of occurrence between wildlands and South Arm exurban forest. Degrees of freedom equal one in all cases.

	Wildlands	Exurban forest	x^2	P value
Crescent honeyeater	**7.14 %**	1.59 %	4.033	0.045
Eastern spinebill	**7.14 %**	1.59 %	4.033	0.045
Flame robin	**4.29 %**	0 %	5.484	0.019
Green rosella	**10.00 %**	3.17 %	3.957	0.047
Noisy miner	0 %	**15.87 %**	12.374	0.000
Satin flycatcher	**7.14 %**	0 %	9.236	0.002
Spotted pardalote	5.71 %	**15.87 %**	4.322	0.038
Yellow-throated honeyeater	17.14 %	**34.13 %**	6.430	0.011

Table 17: Species that significantly differ in frequency of occurrence between wildlands and South Arm exurban modified forest. Degrees of freedom equal one in all cases.

	Wildlands	Modified forest	x^2	P value
Australian magpie	0 %	**5.71 %**	4.158	0.041
Eastern rosella	0 %	**5.71 %**	4.158	0.041
Noisy miner	0 %	**21.43 %**	17.500	0.000
Satin flycatcher	**7.14 %**	0.71 %	6.949	0.008
Tree martin	0 %	**11.43 %**	8.660	0.003

Discussion

This study has demonstrated that the noisy miner responds more strongly to boundaries of historic land clearance than to exurban forest perforation and modification; that, in the absence of edge species, wildland bird species assemblages can inhabit exurban forests and do not suffer disturbance effects due to the proximity or density of houses; that bird species assemblages within exurbia are distributed non-uniformly in accordance with the distribution of distinctive habitat types; and that exurban paddocks do not homogenise bird species communities as much as expected. The survey design enabled a number of hypotheses relating to avifaunal responses to a critically understudied scale of urbanisation to be addressed, which will inform urban planners and policy makers and improve urban avifaunal conservation.

Miner-occupied zones

Interspecific aggression by miners resulted in discrete non-wildland bird communities and regionally low numbers of miner-sensitive species, such as brown thornbills, grey fantails, New Holland honeyeaters, silvereyes, and superb fairy-

wrens, which is consistent with findings from miner-occupied suburbs (Sewell and Catterall, 1998; Parsons *et al.*, 2003) and rural forests (Dow, 1977; Grey *et al.*, 1997; Grey *et al.*, 1998; MacDonald and Kirkpatrick, 2003; Maron, 2009). Unlike suburban regions comprised of parks and gardens (Parsons *et al.*, 2003), miners did not homogenise exurban bird communities irrespective of habitat. Their level of interspecific aggression is evidently proportional to local habitat quality and is strengthened within habitats by disproportionately high numbers of attacks on species that compete with them for food resources (Maron, 2009).

Miner-free zones

Noisy miner territories appear to penetrate beyond land clearance edges markedly less than other edge species (Bolger *et al.*, 1997). In contrast to picnic areas (Piper and Catterall, 2006), exurban housing does not conform to the observations of Dow (1977) that forest perforations create additional edge habitat. Picnic areas probably provide miners with additional resources, such as anthropogenic food, but residential perforations are generally accompanied by gardens, which would provide at least an equivalent amount of resources to picnic areas. Furthermore, road perforations seemingly provide no additional resources, but, if large enough, can be miner-occupied (Piper and Catterall, 2006). Miner responses to road perforations are, however, inconsistent (Piper and Catterall, 2006; Maron, 2009), and parts of South Arm had exceptionally large road perforations that were not inhabited by miners (pers. obs.). In addition to perforation size, the complexity of the vegetation that remains, or, as in the case of gardens, is added, evidently plays a substantial role in determining the likelihood of noisy miner invasion of forest perforation.

Previous studies have demonstrated that various levels of urban development can harbour avifaunal communities as diverse as wildlands (Chapman and Reich, 2007; Bock *et al.*, 2008), and individual species of conservation concern (Caula *et al.*, 2008), but this is the first study to demonstrate that, in the absence of, or with only local dominance of, edge species, wildland bird species assemblages can inhabit an exurban matrix. This has substantial implications for urban avifauna conservation in that it suggests that typical urban effects on bird species communities can be ameliorated by maintaining forest continuity and integrity in the matrix.

Understorey simplification has the potential to dichotomise bird species assemblages. The small non-significant increase in total species richness, and, in the absence of edge species, native species richness, that resulted from woody understorey simplification, conforms to the pattern predicted by the intermediate disturbance hypothesis (Connell, 1978; Roxburgh *et al.*, 2004), and supports previous studies that have found peaks in avifaunal diversity at intermediate levels of urbanisation or landuse intensity (Jokimaki and Suhonen, 1993; Sewell and Catterall, 1998; Blair, 1999; Blair, 2004; Marzluff, 2005; Chapman and Reich, 2007; Blair and Johnson, 2008; Lepczyk *et al.*, 2008). However, the analyses of community similarity suggest that if severe modification was more widespread, modified forests would harbour a bird species assemblage intermediate between regional exurban forest and garden assemblages but probably more diverse than either, such as occurs in suburbs with a native tree canopy but an anthropogenic understorey (Sewell and Catterall, 1998).

If forest integrity could be maintained in suburban density developments, wildland assemblages might still suffer from density-associated stressors such as domestic mesopredators (Odell and Knight, 2001) and disturbance from human activity (van der Zande *et al.*, 1984; Schlesinger *et al.*, 2008). Indeed, previous studies of exurban avifaunas have documented the decline of individual species of songbird (Odell and Knight, 2001), and total bird species richness (Bock *et al.*, 2008), with increasing housing density. The total lack of influence of housing proximity and density on forest species in this study suggests that previously demonstrated housing effects are due to undocumented shifts in species composition associated with anthropogenic vegetation or edge species. Indeed, a previous study found that the main difference between the avifaunas of exurban developments with clustered houses, and exurban developments with dispersed houses, is greater numbers of nest predators and parasites where the housing is clustered (Nilon *et al.*, 1995).

Exurban avoiders and adapters

Urbanisation results in the gradual decline and extirpation of specialists and the invasion of synanthropes (Marzluff, 2005; Blair and Johnson, 2008; Sorace and Gustin, 2010). From the present study, not a single species can conclusively be considered to have been extirpated by the exurbanisation of forests. The two species recorded exclusively in wildlands, the scrubtit and swift parrot, were individually recorded in less than three surveys in total, and are nomadic or rare. Part of exurban South Arm is actually critically important habitat for the threatened swift parrot (Munks *et al.*, 2004).

Many species, however, were only recorded in exurban sites. Most of these were edge species or exotics, but native synanthropes included an endemic corvid and two grassland birds.

Grassland species are less adaptable to urban environments than forest species (Croci *et al.*, 2008), resulting in dramatically contrasting bird species communities across a grassland-urban interface (Sodhi, 1992). Exurbanisation varies in its impact on grassland birds from relatively little (Bock *et al.*, 2008), to a decline in the number of ground and shrub nesters (Maestas *et al.*, 2003). The decline of paddock species as a result of exurbanisation of former agricultural land remains unquantified by the present study. The Australasian pipit *Anthus novaeseelandiae* and the Eurasian skylark *Alauda arvensis* are two species that inhabit non-urban paddocks in South Arm and Kingborough but were not recorded in exurbia. Although grassland species can be particularly vulnerable to reductions in habitat area (Vickery *et al.*, 1994) or isolation within a forest matrix (Soderstrom and Part, 2000), the exurban paddock estate remains large and interconnected, which suggests local variables might be more influential on these species. Ground nesters like pipits and skylarks are more vulnerable to urban development than species that nest in higher strata (Schlesinger *et al.*, 2008) and, as a result, frequently suffer declines due to urbanisation (Marzluff, 2001). These species may thus suffer from exurbanisation due to nest disturbance or predation.

Habitat responses

Two of the paddock specialists in this study, the Tasmanian native-hen, and the masked lapwing, are also ground nesters. However, both of these species were

observed rearing multiple broods per annum, and such fecundity can enable bird species to be successful in urban habitats (Reale and Blair, 2005). The flightless native-hen also benefits from the proximity of native saltmarsh habitats in South Arm (Appendix H), which may provide a source of individuals to buffer exurban mortality, and may have enabled to the flightless native hen to colonise South Arm more rapidly than Kingborough following the creation of habitat through land clearance.

Forest habitats supported species identified as being urban-sensitive, and as such, the traits that typified forest specialists also typify urban sensitivity, such as insectivorous diets or carnivorous diets (Lim and Sodhi, 2004; White *et al.*, 2005; Smith, 2007; van Heezik *et al.*, 2008), open-cup nests (Schlesinger *et al.*, 2008), and small body size (Parsons *et al.*, 2003; White *et al.*, 2005; Smith, 2007).

The preference of Tasmanian scrubwrens for sites with dense understoreys is consistent with a documented correlation between shrub density and the congeneric *Sericornis frontalis* (Creagh *et al.*, 2004). Tasmanian scrubwrens were restricted to Kingborough due to their dependence on broad-leaved moisture-dependent plant species, such as has been found elsewhere (Bentley and Catterall, 1997). Other forest species that suffered from exurbanisation of forest habitats did so inconsistently (tree martin, satin flycatcher and robins) or peaked in gardens.

Tree martins appear to respond inconsistently to exurbanisation due to unquantified aspects of forest maturity. Tree martins roost in the same tree hollows in which they nest (Simpson *et al.*, 1999), and anecdotal observations suggest that they occur most frequently in areas with mature eucalypts, often in proximity to

water (Jones, 1981; Watts, 2002). Thus, anthropogenic habitats might only be exploited when they are proximal to forests containing suitable nest hollows. The satin flycatcher is evidently sensitive to canopy thinning (Appendix G, Appendix I), and as a result its tolerance to exurbanisation appears to increase along a precipitation gradient.

Petroicines are seemingly responding to finer scale factors than habitat variation within exurbia. Robins are perch-and-pounce predators that primarily forage in forest openings. The more uniform distribution of scarlet robins within South Arm is most likely due to less structural contrast between South Arm forests and the micro-niches in which they forage. Correlations between Petroicines and plot variables such as remnant proximity (+ve), paddock patch size (-ve), and fencing (+ve), suggests that their penetration into two dimensional habitats is limited. They may benefit from the installation of perching posts in extensive paddocks (Yosef and Grubb, 1994).

Two of the garden specialists that suffered from forest modification, eastern spinebill and crescent honeyeater, are specialised nectivores. Urbanisation can be a significant stressor on species with specialised diets (Schlesinger *et al.*, 2008), but nectivorous species appear to benefit from the diversity of plants in gardens, and respond more to floristics than physiognomy (Daniels and Kirkpatrick, 2006b; Parsons *et al.*, 2006). Forest modification and stock grazing (Appendix G, Appendix I) may be detrimental to these species because their specific food plants are suppressed or preferentially grazed.

Overall, the assemblage of garden specialists in this study bore some resemblance to classic urban avifaunas, in that it included cosmopolitan anthropophiles, such as the common blackbird, common starling and house sparrow, and also a local hirundine, the welcome swallow (Huhtalo and Jarvinen, 1977; Tweit and Tweit, 1986; Thompson *et al.*, 1993; Jokimaki *et al.*, 1996; Clergeau *et al.*, 1998; Blair, 2001; Jokimaki and Kaisanlahti-Jokimaki, 2003; Smith, 2003; Shwartz *et al.*, 2008; Loss *et al.*, 2009). Typical native synanthropes were also garden specialists, such as little wattlebirds, silvereyes, and local members of the *Platycercus* complex (Garden *et al.*, 2006). Consequently, the assemblage of garden specialists had relatively high proportions of species with functional traits demonstrated to increase resilience to urban development, such as omnivory (Croci *et al.*, 2008; Schlesinger *et al.*, 2008), granivory (Chace and Walsh, 2006) and large body size (Garden *et al.*, 2006). It also included cavity nesters, which exhibit varied responses to urbanisation (Marzluff, 2001; Chace and Walsh, 2006; Schlesinger et al., 2008). Human disturbance can be a significant stressor on cavity nesting species (Schlesinger et al., 2008), but cavity nesters were observed utilising nest boxes in exurban gardens. This may indicate that levels of human disturbance are low in exurbia, or that nest boxes provide a greater buffer against disturbance than natural hollows.

Avifaunal homogenisation

Regional similarity between habitats conformed to the previously identified pattern of managed habitats homogenising avifauna more than non-managed habitats (Blair, 2001; Blair, 2004; Blair and Johnson, 2008). This suggest that exurban paddocks are functioning more like open-space preserves than manicured lawns such as those in

golf-courses, and demonstrates that avifaunal homogenisation is not due to the simplification of vegetation structure. A peak of regional similarity in gardens habitats was hypothesised to result from the tolerance of garden species to human disturbance, but the lack of housing-associated disturbance effects is inconsistent with this hypothesis. Thus, managed habitats, such as gardens, may homogenise bird communities because anthropogenic intervention, which in gardens is in the form of watering, weeding and fertilising, reduces seasonal and spatial variation in resource availability. Inter-regional intrahabitat similarity levels were generally higher than intra-regional interhabitat similarities, which is an indication that South Arm and Kingborough are less disparate than paired ecoregions in other studies (Sorace and Gustin, 2008).

Levels of similarity between sites within habitats did not follow the predicted pattern, which was based on the levels of similarity between sites within habitats in suburban Melbourne that were physiognomically similar to exurban habitats (White *et al.*, 2005). Specifically, paddocks homogenise exurban avifauna less than expected, both between sites within regions, and across regions. The division of historically cultivated earth into many exurban parcels appears to have resulted in a greater diversity of habitat conditions than would have resulted from commercial agriculture or maintained suburban lawns. This management heterogeneity is expressed in temporal and spatial fluctuations in grass height, which can have significant impacts on bird species (Whittingham et al., 2006).

Conclusion

Exurban regions of Hobart harbour a rich community of birds, including numerous forest species that are usually disadvantaged by urbanisation. As a result, exurban avifaunal richness is considerably higher than avifaunal richness in suburban Hobart (Donato, 1989; LeFort, 2002; Daniels and Kirkpatrick, 2006b). Existing suburban estates might be improved, in terms of avifaunal conservation, by replicating the levels of forest cover and habitat heterogeneity found within exurbia. Understorey simplification has the potential to shift species composition of forest assemblages towards a typical urban avifauna. Thus, if many suburban residents are opposed to the establishment of natural forest understoreys, suburbs may need to include forest reserves in order to approach exurban levels of understorey cover and encourage wildland assemblages.

Within exurbia, while most bird diversity was found within forest habitats, some diversity and much heterogeneity were evident amongst paddock bird communities. Similarly, gardens provided habitat for some species that suffered from forest modification, and were optimal habitat for many others. Thus, homogeneous forested estates would harbour greater densities of urban-sensitive species, but lower species and community diversity, than is currently extant within exurbia.

If additional exurban estates are to be created in the future, dry open woodlands will evidently not be disproportionately vulnerable to the colonisation of edge species. However, developments abutting the coast or former agricultural land will probably harbour miners and their cohort.

The influence of exurbia on flightless mammal distribution

Introduction

Despite the catastrophic mammalian extinction rate Australia has experienced over the past 200 years (Short and Smith, 1994), most of the studies of urban and suburban mammal populations, and all of the studies of exurban mammals, have been conducted in the northern hemisphere. Researchers there have investigated mammals in a variety of urban habitats, including domestic gardens (including orchards and productive types), church yards, parklands, a cemetery, and urban remnants of scrub, woodland, and grasslands (Dickman and Doncaster, 1987; Sorace, 2001; Baker *et al.*, 2003; Toms and Newson, 2006). These studies have found that: small muridines are negatively affected by domestic cat abundance and isolation from remnants of natural habitat (Baker *et al.*, 2003); that remnants with naturalistic vegetation structure are better habitat for shrews and voles than maintained habitat patches such as parks and productive gardens, and species display similar habitat preferences in urban and in non-urban areas (Dickman and Doncaster, 1987).

Within the United States, exurban developments within native grassland habitats benefit cottontail rabbits (Bock *et al.*, 2006a) and have no significant effect on rodent communities when the effects of livestock grazing are controlled for (Bock

et al., 2006c). Wild mammals within exurban areas appear to avoid disturbance from humans and / or their commensals by becoming more nocturnal (Vogel, 1989; Harrison, 1997) and, with the exception of cottontail rabbits (Bock *et al.*, 2006a) and possibly bobcats (Harrison, 1998), have been found to concentrate most of their activities in areas with the lowest housing densities (Vogel, 1989; Odell and Knight, 2001; Maestas *et al.*, 2003).

A commonality of the studies of urban mammal assemblages from the northern hemisphere is the prevalence of small to medium-sized generalist species and the rarity of large and stenotopic species. Studies of large-bodied species in urban areas typically focus on infrequent incidences of, or the potential for, human-wildlife conflict (Beier, 1991; Torres *et al.*, 1996; Riley and Decker, 2000; Adams *et al.*, 2006; Storm *et al.*, 2007). The prevalence of studies on small mammals suggests that large-bodied mammals are generally disadvantaged by urbanisation.

No published work has comprehensively documented mammalian responses to urban development in Tasmania. At a broad scale, native mammal distributions within urban Tasmania can be gleaned from the work of Rounsevell *et al.* (1991), while a small number of species or family specific studies have documented the urban denning behaviour and home range size of *Trichosurus vulpecula* (Statham and Statham, 1997), and the reproduction and ecology of bandicoots, primarily *Perameles gunnii*, in various rural / agricultural areas (Heinsohn, 1966; Hocking, 1990; Robinson *et al.*, 1991; Mallick *et al.*, 1997).

The two major studies of Australian urban mammal assemblages document temporal changes within the cities of Adelaide and Melbourne. The metropolitan

area of Adelaide lost fifty percent of its native mammal species between 1836 and 2002, a decline from 40 species to 20 (Tait *et al.*, 2005). Almost all of the areas medium-sized, ground-dwelling marsupials became locally extinct, as did the larger *Vombatus ursinus* (Tait *et al.*, 2005). Van der Ree and McCarthy (2005) used quantitative assessments to infer the probability of persistence of indigenous mammals within the city of Melbourne, based on records from the Atlas of Victorian Wildlife. Their models showed that only 26 of the original 54 species that occurred in Melbourne prior to European settlement had a > 95 % probability of existing at the end of the year 2000. Mammals were less likely to persist in local government areas located within 10 km of the central business district. Small-bodied ground-dwelling mammals were particularly scarce in these inner-city areas, with only *Tachyglossus aculeatus* and *Isoodon obesulus* (out of 16 small species) having a greater than 10 % probability of persistence. In the outer city areas, the probability of persistence of *I. obesulus* increased to > 95 % and *T. aculeatus* to 100 %. The arboreal *T. vulpecula* and *Pseudocheirus peregrinus*, as well as the large-bodied *V. ursinus*, all had a 100 % probability of persistence in both the inner and outer local government areas, mostly due the presence of an extensive area of natural parkland close to the city, which *V. ursinus* was restricted to (van der Ree and McCarthy, 2005).

The disproportionate persistence of smaller-bodied species is not as evident in the Australian urban mammal studies of Tait *et al.* (2005) and van der Ree and McCarthy (2005) as it is in the urban mammal studies from the northern hemisphere. Despite this, there is mounting evidence that small body size is an advantage against contemporary extinction threats to Australian (Smith and Quin,

1996; Cardillo and Bromham, 2001; Cox *et al.*, 2003; Wilson *et al.*, 2003) and other mammal species (Lomolino and Perault, 2007; da Silva and Pontes, 2008), as well as fish (Jennings *et al.*, 1998), and birds (Gaston and Blackburn, 1995). Interpreting the benefits of small body size against extinction risk is difficult, as body size is significantly related to factors such as reproductive capacity and daily energy requirements (Allaine *et al.*, 1987; Cardillo, 2003), which could be the proximal cause of a species susceptibility to extinction, but are less often tested. Adams (1994) suggests that space requirements are critical in determining if a species can exist in urban environments, and smaller-bodied species are at an advantage due to generally having smaller home range sizes. Indeed, it has been shown that small home range size, as well as high reproductive capacity, and the tendency to shelter in burrows or rock piles, increases the likelihood of a species remaining extant through disturbance and demographic pressures such as predation (Smith and Quin, 1996; Cardillo, 2003), and that slow reproductive rates were a more significant factor than body mass in the Late Quaternary global 'megafauna' extinctions (Johnson, 2002; Johnson, 2006). Large home range size is thought to increase the likelihood of local extinction in habitat fragments because certain demographic pressures, such as persecution by humans, can be more evident at reserve edges, and species with large home ranges are more likely to encounter edges by chance (Woodroffe and Ginsberg, 1998). In birds, the relationship between extinction risk and characteristics such as body size, generation time, and level of speciality in breeding habitat, has been shown to vary with different extinction threats (Owens and Bennett, 2000). Small bodied species were found to be more prone to extinction as a result of

habitat loss, whilst large bodied species were significantly more likely to go extinct as a result of mortality through introduced predators and human persecution (Owens and Bennett, 2000). Highly fecund species were significantly less likely to become extinct as a result of introduced predators and human persecution, whilst species with specialist breeding requirements were detrimentally affected significantly more than expected by habitat loss (Owens and Bennett, 2000). The effects of biological characteristics on extinction proneness can also vary between habitat types, with litter size having a significant influence on mammalian extinction proneness in mesic coastal Australia, but not in the arid interior (Cardillo, 2003).

Some species may respond to exurbia purely in terms of habitat alteration, fragmentation, and land use change, all of which are global threats to biodiversity (Sala *et al.*, 2000; McKinney, 2002; Reed, 2004; Foley *et al.*, 2005; Fischer and Lindenmayer, 2007). Fragmentation affects mammal populations through habitat loss (Bentley *et al.*, 2000; Cox *et al.*, 2003), alterations to patterns of dispersal and genetic exchange (Diffendorfer *et al.*, 1995), and by increasing the probability of interactions with potentially detrimental edge effects (Nour *et al.*, 1993; Woodroffe and Ginsberg, 1998; Pardini, 2004). However, some species may benefit from fragmentation due to increased habitat heterogeneity at the landscape level. Landscape heterogeneity has been shown to be positively related to biodiversity on European farms (Benton *et al.*, 2003) and the local diversity of frugivorous birds, and herbaceous and shrubby plant species, in semi-rural landscapes in Costa Rica (Luck and Daily, 2003; Mayfield and Daily, 2005).

Within Tasmania, the eastern barred bandicoot *P. gunnii* has undergone a significant shift in distribution in response to habitat alteration. Natural habitats for the barred bandicoot are native grasslands and grassy woodlands (Hocking, 1990), which were historically restricted to the Midlands and largely absent from the wetter south-eastern and northern parts of the state, which supported forests (Kirkpatrick *et al.*, 1988). The natural habitats of the barred bandicoots have been extensively cleared for agriculture (Kirkpatrick *et al.*, 1988) to an extent that there is no longer sufficient ground cover to support a population of bandicoots (Hocking, 1990). In contrast, many formerly forested areas have been subjected to patchy clearance, resulting in a mosaic of ground cover and cleared land that is ideal for barred bandicoots, making such regions the stronghold of the species in Tasmania (Hocking, 1990).

The distributional shift of *P. gunnii* demonstrates that even species that occur naturally in open habitats may require shrub cover at the local level. Indeed, the amount of ground cover is the most important determinant of suitable barred bandicoot habitat (Mallick *et al.*, 1997) and they remain within 60 m of cover when foraging (Dufty, 1994a). Suitable ground cover for bandicoot shelter does not need to be comprised solely of native flora. Thickets of African boxthorn *Lycium ferocissimum*, blackberry *Rubus fruticosus*, gorse *Ulex europaeus*, and even scrap heaps of metal, have been recorded as sites for bandicoot shelter (Heinsohn, 1966; Dufty, 1994a; Chambers and Dickman, 2002). Similarly, *Potorous tridactylus* is associated with dense understorey vegetation at the landscape level, but utilise a diversity of habitat types at the local level (Bennett, 1993).

The herbivorous macropods *Thylogale billardierii* and *Macropus rufogriseus* reach their peak population densities where native vegetation abuts improved pasture (Rounsevell *et al.*, 1991). During the day, *Thylogale* spp. utilise forested habitats for protection from predators and harsh weather, and at night they remain largely sedentary whilst foraging in pasture (Johnson, 1980; Vernes *et al.*, 1995). Another large Tasmanian herbivore, *V. ursinus*, is dependent on pasture comprised of perennial grasses for foraging, but requires forested areas for burrow locations and protection from predators (Mallett and Cooke, 1986). The high abundances of large herbivores at the forest / pasture interface attracts relatively high abundances of carnivorous Tasmanian devils *Sarcophilus laniarius* (Pukk, 2005).

In the first study to document the responses of mammals to exurban development in Australia, the relative abundances of flightless mammals on exurban properties will be compared to relative abundances in corresponding wildlands and tested against various exurban property characteristics. Several questions are investigated: (1) Do any species of flightless mammals differ in their relative abundances between wildlands and exurbia? (2) Do the most successful species within exurbia share any biological or ecological traits? (3) Are mammalian species distributed uniformly between the two exurban regions of Hobart? (4) Within exurbia, are there relationships between mammal species and property vegetation and / or human artefacts such as chicken yards and dams? (5) Does property location, in terms of surrounding housing density, remnant proximity, and landscape tree coverage, have an effect on the type of wild mammals that utilise a property?

Methods

Sampling of flightless mammals

Consideration of sampling techniques

Live trapping and hair tubes are often used when sampling small mammal species (e.g. Adams and Geis, 1983). However, trapping in particular is labour intensive and has low success rates in urban areas. *T. vulpecula* is abundant in urban areas (van der Ree, 2004) but has been trapped with less than 5 % success in the Tasmanian city of Launceston (Statham and Statham, 1997). Small Tasmanian mammal species also have a negative trap response in areas trapped repeatedly (Johnson, 1987b; Hird, 1996), making estimates of occurrence frequencies based on repeated visits difficult. In addition to problems with sampling efficiency, live trapping can be controversial with members of the public. When first approached about participating in this study, numerous landowners mentioned that they would be uncomfortable with live trapping of mammals on their property, creating the potential for a biased sample of properties. Thus, it was considered small mammal trapping would be unacceptably inefficient and controversial.

Hair tube sampling is less labour intensive than trapping in terms of data capture and is probably considered harmless by most people. It is, however, only useful for sampling small to medium sized ground-dwelling mammals and would thus have required an additional method be used for the sampling of arboreal and larger-bodied species.

Spotlighting survey can discriminate against very small bodied ground-dwelling mammals, but is an effective method for sampling larger and small to medium-sized

mammals, both ground-dwelling and arboreal (Driessen and Hocking, 1992). While a survey method with a size-based discrimination considerably limits the conclusions that can be drawn from correlations between the relative abundances of exurban mammals and species biology and ecology, spotlighting was chosen as the primary method of mammal sampling mainly on the grounds that it would be efficient in terms of data return / time spent in field, which is an unfortunate, but necessary, consideration that has to be made with a multifaceted doctoral study.

The effects of time and weather

Rain, heavy rain in particular, has been found to significantly affect the detectability and / or activity levels of numerous species, including peramelids (Gordon, 1974), *Petaurus* spp. (Davey, 1990), *T. billardierii* (Driessen and Hocking, 1992), *M. rufogriseus* (Driessen and Hocking, 1992) and *T. vulpecula* (Driessen and Hocking, 1992). Windy conditions have been found to reduce the counted numbers of *T. billardierii* and *T. vulpecula* (Driessen and Hocking, 1992) and the likelihood of detecting *Petaurus* calls (Davey, 1990). Air temperature and cloud cover have been found not to significantly influence spotlight survey counts of Tasmanian mammal species, although there was a slight indication that cloud cover was associated with lower counts of *T. billardierii* (Driessen and Hocking, 1992). This association was due to a higher chance of rainfall on cloudy nights and by removing nights when rainfall occurred from the data set, there was no evidence of cloud cover influencing *T. billardierii* counts (Driessen and Hocking, 1992). A high level (80-100 %) of cloud cover has been found to be beneficial when detecting *Petaurus* species (Davey, 1990). This may be related to the darkness provided by cloud cover, as counted

numbers of *T. billardierii* and *M. rufogriseus* have found to be lower on moonlit nights (Driessen and Hocking, 1992), and anecdotal evidence suggests that many nocturnal species are particularly cautious and hard to detect on moonlit nights.

In addition to the detectability variations due to weather fluctuations, the time of day and year that a spotlight survey is conducted can influence results. Driessen and Hocking (1992) suggest that numbers of mammals detected through spotlighting may undergo seasonal change due to rapid population changes following breeding seasons, and Southwell and Fletcher (1985) showed that the time of night at which a spotlight survey is conducted has a significant, but varied (both between species and habitat types) influence on mammal detectability.

Based on the above findings, it was decided that spotlight surveys conducted in both exurban and natural areas would be subject to some weather and time-related sampling restrictions in order to provide a level of standardisation. Therefore, spotlight surveys were only carried out in dry conditions, with rainfall no heavier than drizzle, with little to no wind, on dates at least three days separated from the full moon. All surveys were carried out within five hours of sunset. Exurban properties and wildland controls were never surveyed twice in one night.

Time of year is difficult to standardise due to varying population fluctuations displayed by species with seasonally and / or environmentally different breeding patterns. Even when dealing with a single species, relative measures of density, such as capture rates, have been found to vary in their temporal fluctuations between different habitat types (Stoddart and Braithwaite, 1979). None the less, in an attempt to counter seasonal variations, each survey site was spotlighted no more

than once during the winter months of June, July and August, and the remainder of spotlight surveys were conducted in the warmer months between September and March, inclusive.

Spotlight surveys

Spotlight surveys were carried out on foot with a hand-held one million candle power spotlight. Standardising spotlighting effort across a variety of habitats is inappropriate because the detection probability of mammals is likely to change in relation to habitat complexity, with the denser, more structurally complex habitats making mammal detection more difficult. Therefore, all habitat types were grouped into three broad types, 'paddock', 'open forest', and 'dense forest' based on vegetation structure and complexity. Spotlight effort was largely fixed within, but varied between these three habitat types. Any habitat could be placed into one of the three broad categories on the basis of the distance at which a small, ground-dwelling mammal could be accurately observed from: paddocks = > 50 m, open forest = 15 – 50 m, dense forest = < 15 m. Paddocks were surveyed at a rate of 0.5-1 min/half-hectare; dry, open forests at 1-3 min/half-hectare; and wet, dense forests at 3-6 min/half-hectare, with time variation within and between habitat types being dependent on vegetation complexity (Table 18). To test the adequacy of the survey times for the three broad habitat types, 10 representative half-hectare plots of each of the three habitat types were randomly selected within the study area. Each of the representative sites was surveyed for the standard amount of time and then the survey immediately repeated 9 consecutive times for paddocks, and 5 consecutive times for open and dense forest. A cumulative list of species observed within the site

was kept so that it could be tested if species became more likely to be recorded as the survey time was increased by an order of magnitude.

All spotlight surveys were conducted along tracks, roads and fire-breaks wherever possible. In areas of open-forest lacking these established paths, spotlighting was conducted along a path of minimal resistance / disturbance. If an area of very dense forest lacked established paths then spotlighting was conducted along the perimeter, as encroaching into areas of very dense forest created unacceptable disturbance. Each exurban property was surveyed as completely as possible within those constraints. All of the wildlands control sites had adequate tracks from which to conduct spotlight surveys. A distance of 500 m was taken as equivalent of the mean distance traversed whilst sampling a typical 2 ha exurban property, and was thus the transect distance for each of the wildland control sites. Each 100 m of a wildland control transect was deemed equivalent to one half-hectare of exurbia, and thus the time spent surveying each 100 m section of the 500 m control transects was equivalent to the relevant time per habitat category.

Between October 2006 and March 2008 each exurban property was spotlighted 6 times, whilst the wildlands control sites were surveyed between 5 and 12 times each, depending on the prevalence of that forest type within the exurban study area. In total, 510 exurban and 87 wildland spotlight surveys were conducted. During each spotlight survey only the presence or absence of mammal species was noted, rather than abundance, because this is a more appropriate method of data collection in studies with a low number of sampling periods and a low expected number of recordings of each species (Joseph *et al.*, 2006).

Table 18: Variation in spotlighting effort between habitat types

	Increasing time spent spotlighting →
Paddock (0.5-1 min. / half-hectare)	Short grass-no trees/shrubs → Short grass-few trees/shrubs → Long grass-no trees/shrubs → Long grass-few trees shrubs
Open forest (1-3 min. / half-hectare)	Grassy woodland → Forest with modified / cleared understorey → Dry sclerophyll forest
Dense forest (3-6 min / half-hectare)	Dry sclerophyll with heathy understorey → Wet sclerophyll forest

Landowner observations

As part of the landowner survey discussed in more detail in the next chapter, landowners were provided with a list of species (Table 19) and were asked to tick a box beside the species that they were certain inhabited or visited their property. The survey did not include any photos or specific information for identifying animal species. Participants were urged to contact the author for help if they were not completely certain of animal identification. Those that requested help were assisted over the phone or in person and / or supplied with photos of the species in question. On receipt of the completed surveys, any reports of rare or difficult to identify species were investigated by means of conversations with landowners. Reports were only accepted when the landowner demonstrated a high level knowledge and confidence in the reported sighting. Reports of pygmy possums were collated, due to extreme difficulty in identifying between the two, but were not disregarded, as there are few species from any other genera with which they could be confused with.

Table 19: Species that were included on the list provided to exurban landowners. Landowners were provided with common names only. Latin binomials and families are also listed for reference.

Common name	Latin binomial	Family
Eastern and little pygmy possums	*Cercartetus nanus* and *C. lepidus*	Burramyidae
Dusky antechinus	*Antechinus swainsonii*	Dasyuridae
Eastern quoll	*Dasyurus viverrinus*	Dasyuridae
Spotted-tailed quoll	*Dasyurus maculatus*	Dasyuridae
Swamp antechinus	*Antechinus minimus*	Dasyuridae
Tasmanian devil	*Sarcophilus laniarius*	Dasyuridae
White-footed dunnart	*Sminthopsis leucopus*	Dasyuridae
European hare	*Lepus capensis*	Leporidae
European rabbit	*Oryctolagus cuniculus*	Leporidae
Bennett's wallaby	*Macropus rufogriseus*	Macropodidae
Tasmanian pademelon	*Thylogale billardierii*	Macropodidae
European black and brown rats	*Rattus rattus* and *R. norvegicus*.	Muridae
House mouse	*Mus musculus*	Muridae
Long-tailed mouse	*Pseudomys higginsi*	Muridae
Swamp rat	*Rattus lutreolus*	Muridae
Water rat	*Hydromys chrysogaster*	Muridae
Platypus	*Ornithohynchus anatinus*	Ornithohynchidae
Eastern barred bandicoot	*Perameles gunnii*	Peramelidae
Southern brown bandicoot	*Isoodon obesulus*	Peramelidae
Common ringtail possum	*Pseudocheirus peregrinus*	Petauridae
Sugar glider	*Petaurus breviceps*	Petauridae
Common brushtail possum	*Trichosurus vulpecula*	Phalangeridae
Long-nosed potoroo	*Potorous tridactylus*	Potoroidae
Tasmanian bettong	*Bettongia gaimardi*	Potoroidae
Echidna	*Tachyglossus aculeatus*	Tachyglossidae
Common wombat	*Vombatus ursinus*	Vombatidae

Heritable traits potentially influencing extinction proneness

Data for home range size, fecundity and body mass were collected from published articles, books and theses, based predominantly on, but not limited to, field research

conducted in Tasmania. For home range size, only data for female individuals were used, as males tend to have much larger and more variable ranges (Heinsohn, 1966; Kitchener, 1973). Fecundity is considered as the mean number of offspring produced per year per adult female, and was calculated by multiplying mean litter size with the mean number of reproductive events per year. Fecundity incorporates variation due to litter size and inter-birth intervals and is thus a better indicator of reproductive capacity than the component variables by themselves (Allaine *et al.*, 1987; Johnson, 2002). For all variables in which multiple sources were found, the mean was calculated, with appropriate weight being given to studies with higher *n* values. If no studies were found on a particular species then data from similar sized congenerics were used.

Exurban property location and composition

At a property scale, the presence of the following habitat types and property characteristics were recorded nominally: lawn (≥ 100 m^2)*; pasture paddock (≥ 1000 m^2)*; grassy woodland (≥ 1000 m^2)*; orchard (≥ 50 m^2)*; rank grass / tussocky paddock (≥ 1000 m^2)*; > 25 % forest (modified or exurban) cover*; > 50 % forest cover; > 25 % exurban forest cover; > 50 % exurban forest cover; predominately mudstone substrate; substrate of undefined (sandy) soils; dolerite substrate; dune grassland (≥ 500 m^2)*; saltmarsh (≥ 500 m^2)*; modified forest (≥ 1000 m^2)*; productive garden*; woodland garden*; mixed minimal input garden*; showy flower garden*; native garden*; windbreak*; water, in the form of a dam and / or river*; chicken yard.

Nominal location characteristics were: a wildland remnant ≥ 100 ha within 250 m; and a wildland remnant ≥ 100 ha within 250 m and not on the opposite side of a sealed road.

Interval variables were: habitat richness - a cumulative total of the nominal property variables listed above and marked with asterisks; surrounding housing density - the total number of houses located within 250 m of the centre of a property; the extent of forest cover in the surrounding (1 km) terrestrial landscape – this was calculated by measuring the area within a 1km radius (around the centre of a property) covered by: trees at forest or woodland densities (collectively termed forest for this variable); paddocks; and lagoons and / or the ocean. The extent of area covered by lagoons and / or the ocean was then subtracted from the total and the extent of forest in the terrestrial component of the surrounds expressed as a percentage value.

Data analysis

Frequency of occurrence was taken as a measure of relative abundance and is expressed as a percentage of surveys in which a species or group was recorded, divided by the total number of spotlight surveys (SS) conducted at a given region or site. Fisher's exact probability test was used to test differences in species frequencies of occurrence between wildlands and exurbia, between exurban regions, and between pairs of surveys of different durations in the spotlight survey efficiency test.

Species exurban distributions are expressed as a percentage of properties on which a species was recorded as present during at least one SS, or reported as

present by the landowner (LO), divided by the total number of properties surveyed or landowner reports received in the given region. Data from SS and LO are not combined. Variation in species distributions between regions, and between the species distributions observed by these two different methods of data collection were tested using Fisher's exact probability test.

The Exurban Adaptability Ratio (EAR) was calculated as an index of species relative abundances across the exurban-wildlands interface. EAR is calculated by dividing a species' exurban frequency of occurrence in a single region by the species' frequency of occurrence in the corresponding wildlands. Within the data sets for each region, EAR was only calculated for species that occurred in both the given exurban region and its corresponding wildlands, or had a percentage frequency of occurrence of > 5 % in only one of exurbia or wildlands. Species which met the > 5 % frequency of occurrence requirement in exurbia, but were absent from corresponding wildlands, have an EAR value of infinity. Species that met the > 5 % frequency of occurrence requirement in wildlands, but were absent from the corresponding exurban region, have an EAR value of zero. To avoid correlation biases that might result from a large spectrum of EAR values, EAR values were given an ordinal ranking from lowest to highest within each region. If two species had an equal EAR value, their ordinal ranking was based on their absolute frequencies of occurrence, with the species with the higher exurban frequency of occurrence being assigned the higher ranking. Species traits, body mass, fecundity and home range area, were also rank ordered from lowest to highest. Correlations between EAR rankings and trait rankings were tested using Pearson's Product Moment Correlation

Coefficient. EAR correlation tests were done with and without the European rabbit included in the data set, so as to ensure this very fecund exotic species was not confounding the results. The reasoning for including the rabbit in any EAR analyses was that it is not uniformly abundant across the landscape, and thus it's adaptability to exurbia may well be influenced by the same life history traits as native species. Having an exotic origin does not necessarily result in adaptability to exurbia, as evidenced by the rarity of European hares in exurbia.

The frequency of occurrence (SS) and percentage distribution (SS and LO) of each mammalian species recorded was tested against all the nominal and interval property and location variables. Chi-squared and Fishers exact probability test were used for tests between class variables, One-Way ANOVA was used for tests between continuous and class variables, and Pearson's Product Moment Correlation was used for tests between continuous variables.

The relationships between all independent variables tested against mammalian response variables in the current and the following chapter were explored using Chi-squared, Fisher's exact probability test, One-Way ANOVA and Pearson's product moment correlation. The strongest relationships are presented in constellation diagrams (Appendix M and Appendix N) and all significant relationships were considered in discussion of results and mentioned in text when potentially influential.

In all cases a level of $P < 0.05$ was taken to denote a significant relationship.

Throughout the text, mammal species are mostly referred to by their Latin binomials. Occasionally the common names listed in Table 19 are used for variety.

Results

Spotlight survey efficiency and comparison with landowner reports

Increasing the spotlight survey time for any of the habitat types was not significantly more efficient at detecting more species than standard length surveys (Appendix O).

The exurban distributions of macropods, possums, the eastern barred bandicoot, and the European rabbit, were not significantly different between spotlight surveys and landowner reports (Table 20). Landowners in Kingborough reported *P. tridactylus* on significantly more properties than it was recorded by spotlight, but the reverse pertained for *B. gaimardi* in the same region. South Arm landowners reported *I. obesulus* from significantly more properties than it was recorded by spotlight. Within each exurban region, diurnal monotremes were markedly under-represented in spotlight surveys. In terms of nocturnally active species, spotlight surveys also markedly under-sampled dasyurids, *P. breviceps*, and rodents, particularly introduced species.

Relative abundances – spotlight surveys

Two species, *O. cuniculus* and *P. gunnii*, were uniformly more frequently recorded in exurbia than wildlands (Table 21). *M. rufogriseus* was the only species significantly more frequently recorded in wildlands than in either exurban region.

Table 20: Percentage distribution of mammalian species and groups across exurban properties in each region according to two methods of data collection, spotlight surveys (SS), and reported landowner observations (LO). Within each row, no significant difference in a paired comparison is indicated by shared uppercase letters for comparisons between methods within regions, and shared lowercase letters for comparison between regions for a single method – *i.e.* reader should make no inferences from variation in uppercase letters between regions and variation in lowercase letters between methodologies. Values with no adjacent letter could not be included in analyses due to ubiquity or rarity of species, which invalided some paired analyses. Values in parentheses could not be satisfactorily confirmed but are plausible.

	Kingborough SS (n = 38)	Kingborough LO (n = 33)	South Arm SS (n = 47)	South Arm LO (n = 40)
A. minimus	0.00	0.00	0.00	0.00
A. swainsonii	0.00	9.09 x	0.00	0.00 x
B. gaimardi	35.48 Aa	15.15 Bx	5.13 Cb	5.00 Cx
D. maculatus	0.00	6.06 x	0.00	0.00 x
D. viverrinus	0.00	12.12 x	0.00	12.50 x
H. chrysogaster	0.00	3.03 x	0.00	5.00 x
I. obesulus	19.35 Aa	19.35 Ax	38.46 Ca	56.41 Dy
L. capensis	0.00	0.00 x	0.00	2.50 x
M. rufogriseus	9.68 Aa	60.61 Ax	0.00 a	5.00 y
M. musculus	0.00	84.85 x	0.00	100.00 y
O. cuniculus	80.65 a	100.00	76.92 Ca	94.74 C
R. lutreolus	0.00	9.09 x	0.00	0.00 x
European *Rattus* spp.	0.00	57.58 x	0.00	41.03 x
O. anatinus	0.00	15.15 x	0.00	0.00 y
P. breviceps	3.22 Aa	18.18 Ax	5.13 Ca	12.50 Cx
P. gunnii	67.74 Aa	63.64 Ax	51.28 Ca	45.00 Cx
P. higginsi	0.00	(9.09) x	0.00	(5.00) x
P. peregrinus	32.26 Aa	48.48 Ax	28.21 Ca	70.00 Cx
P. tridactylus	32.26 Aa	42.42 Bx	10.26 Cb	22.50 Cx
Pygmy possums	0.00	12.12 x	0.00	2.50 x
S. laniarius	0.00	15.15 x	0.00	2.50 x
S. leucopus	0.00	0.00	0.00	0.00
T. aculeatus	0.00	60.61 x	0.00	62.50 x
T. billardierii	74.19 Aa	69.70 Ax	2.56 Cb	2.50 Cy
T. vulpecula	87.10 Aa	96.77 Ax	89.74 Ca	97.44 Cx
V. ursinus	0.00	6.06 x	0.00	0.00 x

While no species or groups differed significantly in their relative abundances between wildland areas, some did so between exurban regions, inferring non-uniform responses to exurbanisation. Macropods and potoroids were significantly less frequently recorded in South Arm than in Kingborough (Table 21). The same pattern was evident in the percentage distributions of these groups across exurban properties (Table 20). In comparison to both wildlands and South Arm, *T. vulpecula* was less frequently recorded in Kingborough; it was, however, distributed across an equivalent proportion of properties in each exurban region (Table 20).

Overall there was no significant difference in mean survey species richness between either of the exurban regions and the corresponding wildlands, but mean native species richness was significantly lower in South Arm.

Species biology and ecology

Home range size

Of the taxa that met the requirements for EAR analysis, members of the perameloidea and phalangerida have significantly smaller mean female home range sizes than would be expected based on their body mass, while members of the potoroidea and macropodoidea have significantly larger mean female home range sizes than expected (Table 22) (Cardillo, 2003).

Studies of congeneric species give an indication home range size for *Thylogale billardierii*. *T. stigmatica* have small (mean = 2.26 ha) home ranges that are variable between individuals (range 0.82-3.70 ha) (Vernes *et al.*, 1995). Both *T. stigmatica* and *T. thetis* have distinct diurnal and nocturnal components to their overall home range (Johnson, 1980; Vernes *et al.*, 1995). In both cases the nocturnal range

comprises forest edges and adjacent pasture, and the diurnal range is comprised entirely of forest habitat (Johnson, 1980; Vernes *et al.*, 1995). In the case of *T. stigmatica*, their nocturnal range (mean = 1.0 ha) is slightly smaller than their diurnal range (mean = 1.67 ha) (Vernes *et al.*, 1995). *T. thetis* are predominantly edge dwellers, and tend not to range farther than 70 m onto pasture and 500 m into forest habitat (Johnson, 1980).

In a 62 ha remnant of dry sclerophyll bushland near Hobart, home ranges of resident adult male *P. tridactylus* were found to vary between 12.0 and 34.4 ha, with a mean range of 19.4 ha (Kitchener, 1973). Resident female *P. tridactylus* had significantly smaller home ranges, ranging from 2.0 to 11.5 ha, with a mean of 5.2 ha (Kitchener, 1973). The home range estimates for the male *P. tridactylus* were still increasing with capture repeats (Kitchener, 1973). In the northern Midlands of Tasmania, *B. gaimardi* has been found to have a similarly large mean home range of 61 ha (males and females combined), with results from the few male individuals tracked indicating a home range size larger than that of females (Taylor, 1993b).

Fecundity

All bar one of the species (*Hypsiprymnodon moschatus*) within the macropodidae and potoroidae have a litter size of one (Lee and Ward, 1989), which is significantly smaller than expected for animals of their body mass (Cardillo, 2003). Both *Thylogale billardierii* and *Macropus rufogriseus* are seasonal breeders (Rose and McCartney, 1982; Hume *et al.*, 1989), with *T. billardierii* breeding only once per year and *M. rufogriseus* capable of reproducing 5 times in every 4 years (Lee and Ward, 1989). The two potoroids in this study, *Potorous tridactylus* and *Bettongia gaimardi*, are

polyestrous, and as such have higher fecundities than their larger bodied macropodid counterparts (Hughes, 1962; Heinsohn, 1968; Rose, 1987b; Lee and Ward, 1989).

Table 21: Species frequencies of occurrence (SS) in each exurban region and the corresponding wildlands. Shared letters within each row indicate no significant difference. N values refer to the total number of surveys conducted in each area.

	Kingborough wildlands (n = 43)	Exurban Kingborough (n = 228)	South Arm wildlands (n = 44)	Exurban South Arm (n = 282)
Bettongia gaimardi	13.79 a	9.70 a	2.63 ab	0.70 b
Dasyurus viverrinus	3.45 ab	0.00 a	5.26 b	0.00 a
Isoodon obesulus	3.45 a	4.64 a	2.63 a	8.80 a
Macropus rufogriseus	17.24 a	5.91 b	31.58 a	0.00 c
Oryctolagus cuniculus	0.00 a	44.30 b	5.26 a	50.00 b
Perameles gunnii	3.45 a	22.36 b	0.00 a	21.13 b
Petaurus breviceps	0.00 a	0.42 a	0.00 a	1.41 a
Potorous tridactylus	0.00 ab	7.59 a	7.89 ab	3.17 b
Pseudocheirus peregrinus	13.79 a	10.70 a	5.26 a	5.99 a
Thylogale billardierii	44.83 ab	56.96 a	28.95 b	0.70 c
Trichosurus vulpecula	68.97 a	41.35 b	57.89 ab	51.41 a
Vombatus ursinus	3.45 a	0.00 a	0.00 a	0.00 a
Mean species richness exurban property $^{-1}$	-	4.355 a	-	3.077 b
Mean native species richness exurban property $^{-1}$	-	3.548 a	-	2.308 b
Mean species richness survey $^{-1}$	1.724 ab	2.042 a	1.474 b	1.433 b
Mean native species richness survey $^{-1}$	1.724 a	1.599 a	1.421 a	0.933 b

Table 22: Life history and ecological characteristics potentially affecting species adaptability to exurbanisation.

*** 1 = Blackhall (1980); 2 = Fisher *et al*. (2001); 3 = Fletcher (1978); 4 = Godsell, 1982 in Bryant (1988); 5 = Heinsohn (1966); 6 = Heinsohn (1968); 7 = Hird (1996); 8 = How *et al.* (1984); 9 = Hughes (1962); 10 = Hughes *et al.* (1965); 11 = Johnson (1980); 12 = Johnson (1987a); 13 = Jones *et al.* (1994); 14 = Kitchener (1973); 15 = Lee and Ward (1989); 16 = Lobert (1990); 17 = McCartney (1978); 18 = Moloney (1982); 19 = Myers *et al.* (1989); 20 = Quin (1986); 21 = Reimer (1992); 22 = Rose (1987a); 23 = Rose and McCartney (1982); 24 = Statham and Statham (1997); 25 = Stoddart and Braithwaite (1979); 26 = Taylor (1993b); 27 = Walker (1977).**

♦ Data from similar sized congenerics † Maximum

	Mean female body mass (gm)	Fecundity (mean number of offspring / year)	Mean female home range size (ha)	References*
B. gaimardi	1800	3.5†	50.2	15, 22, 26
D. viverrinus	890.7	4.9	35†	1, 3, 4
I. obesulus	572.8	5.6	1.34	5, 16, 18, 25
M. rufogriseus	8610.7	1.25†	11.8	12, 27
O. cuniculus	1328	28.0	3.5	19
P. gunnii	841.4	9.13	3.24	5, 18, 20, 21
P. peregrinus	835	1.97	0.88	8, 10, 13♦, 15
P. tridactylus	1075	2.0	5.8	6, 7, 9, 14
T. billardierii	5000	1.8†	10.51	11♦, 17, 23
T. vulpecula	2078	1.1	2.03	2, 15, 24

Members of the dasyuroidea and perameloidea have significantly larger litter sizes than is predicted by their body mass (Cardillo, 2003). Both *Perameles gunnii* and *Isoodon obesulus* are polyestrous and highly fecund (Stoddart and Braithwaite, 1979; Lobert, 1990; Dufty, 1991; Reimer, 1992) and are thought to have very brief gestation periods between 12 and 21 days, which is the recorded period for *Perameles nasuta* (Lyne, 1964). Their offspring grow quickly and male and female of both *P. gunnii* and *I. obesulus* reach sexual maturity around the age of 5 and 3 months respectively (Heinsohn, 1966; Dufty, 1994b). In Hamilton, Victoria, the

number of females *P. gunnii* lactating at any one time has been found to be, on average, 85 %, increasing to 100 % during spring and autumn (Dufty, 1994b). Remarkably, bandicoots can be in oestrus whilst lactating, thus allowing a new litter to be born immediately after the pouch is vacated (Stoddart and Braithwaite, 1979). Stoddart and Braithwaite (1979) have suggested that the reproductive strategy of *I. obesulus* oscillates around a continuum similar to the semelparity / iteroparity continuum, but the range of variation is narrow and skewed towards the iteroparous end of the scale.

The influence of heritable traits on exurban adaptability

The EAR for species recorded by spotlight within Kingborough (Table 23) was not significantly related to female body mass (r = - 0.533, *P* = 0.139) or home range size (r = - 0.200, *P* = 0.606), but significantly related to mean fecundity (r = 0.783, *P* = 0.013). With the introduced *O. cuniculus* removed the index, EAR was not significantly related to female body mass (r = - 0.595, *P* = 0.122) or home range size (r = - 0.262, *P* = 0.531), but was still close to significantly related to mean fecundity (r = 0.690, *P* = 0.058).

Within the South Arm region there were close to significant relationships between EAR (Table 24) and female body mass (r = - 0.612, *P* = 0.060) and mean fecundity (r = 0.600, *P* = 0.067), and a significant negative relationship between EAR and home range size (r = - 0.721, *P* = 0.019). With *O. cuniculus* removed from calculations, EAR was not significantly related to mean fecundity (r = 0.467, *P* = 0.205) but significantly related to female body mass (r = - 0.733, *P* = 0.025) and home range size (r = - 0.767, *P* = 0.016).

Table 23: EAR values and rankings, and species trait rankings, for Kingborough species that qualified for EAR analysis.

	EAR	EAR rank	Body mass rank	Fecundity rank	Home range size rank
Macropus rufogriseus	0.34	1	9	2	8
Trichosurus vulpecula	0.60	2	7	1	3
Bettongia gaimardi	0.70	3	6	6	9
Pseudocheirus peregrinus	0.80	4	2	4	1
Thylogale billardierii	1.27	5	8	3	7
Isoodon obesulus	1.35	6	1	7	2
Perameles gunnii	6.48	7	3	8	4
Potorous tridactylus	∞	8	4	5	6
Oryctolagus cuniculus	∞	9	5	9	5

Species associations with exurban land cover and artefacts

With the exception of lawns and woodland gardens, which were found on a disproportionately large number of Kingborough properties, garden types and human artefacts were distributed uniformly across the two exurban regions (Table 25). In addition, properties within each region did not significantly differ in mean habitat heterogeneity, size, or surrounding housing density. Geographic variation between the two regions was evident in local geology and the proportion of properties that had areas of coastal land cover types, saltmarsh and dune grassland. Purely in terms of land cover, the regional exurban landscapes did not significantly differ (mean proportion of forest in the surrounding (1 km) terrestrial landscape). However, the significant regional variation in the proportion of properties with

extensive (> 50 %) forest cover and the proportion of properties proximal to a wildland remnant, demonstrate that a greater proportion of South Arm properties are located within forest, rather than on the forest periphery.

Table 24: EAR values and rankings, and species trait rankings, for South Arm species that qualified for EAR analysis.

	EAR	EAR rank	Body mass rank	Fecundity rank	Home range size rank
Macropus rufogriseus	0.00	1	10	2	8
Dasyurus viverrinus	0.00	2	4	7	9
Thylogale billardierii	0.02	3	9	3	7
Bettongia gaimardi	0.27	4	7	6	10
Potorous tridactylus	0.40	5	5	5	6
Trichosurus vulpecula	0.89	6	8	1	3
Pseudocheirus peregrinus	1.14	7	2	4	1
Isoodon obesulus	3.34	8	1	8	2
Oryctolagus cuniculus	9.48	9	6	10	5
Perameles gunnii	∞	10	3	9	4

Kingborough

Types of gardens and planted vegetation were significantly related to mammal taxa (Table 26), but in many cases were also strongly related to more extensive forms of land cover. Windbreaks were strongly associated with properties without high levels of tree cover. Within Kingborough, measures of forest (both exurban and modified) and woodland cover were significantly related to numerous individual species (Table 27); these were generally positive relationships, but negative in the cases of

Table 25: Property characteristics within each exurban region. Unless otherwise indicated, numerical values represent percentage of properties in each region that have the given property characteristic. Shared letters within rows indicate no significant difference between regions.

	Kingborough (n= 37)	South Arm (n = 49)
Mean habitat richness	5.707 a	5.225 a
Mean property size (ha)	2.0889 a	2.1620 a
Natural and agricultural land cover types		
> 25 % exurban forest cover	56.10 a	67.50 a
> 50 % exurban forest cover	26.83 a	40.00 a
> 25 % forest cover	65.85 a	77.50 a
> 50 % forest cover	39.02 a	65.00 b
Dune grassland	0.00 a	7.50 a
Grassy woodland	24.39 a	42.40 a
Modified forest	34.15 a	30.00 a
Pasture paddock	63.41 a	37.50 b
Saltmarsh	0.00 a	10.00 b
Tussocky paddock	24.39 a	20.00 a
Gardens and artefacts		
Chicken yard	23.68 a	28.21 a
Lawn	73.17 a	42.50 b
Mixed minimal input garden	29.27 a	22.50 a
Native garden	41.46 a	35.14 a
Orchard	31.71 a	27.50 a
Productive garden	38.46 a	48.72 a
Showy flower garden	21.95 a	25.00 a
Water: dam and / or river	73.17 a	58.97 a
Windbreak	41.46 a	43.59 a
Woodland garden	19.51 a	5.00 b
Substrate		
Mudstone	24.39 a	65.00 b
Undefined soils	24.39 a	35.00 a
Igneous	51.22 a	0.00 b
Property location		
Housing density within 250 m (mean)	5.585 a	6.775 a
Proportion of forest in surrounds (1 km)	58.39 a	62.93 a
Proximal (250 m) to 100 ha wildland remnant	80.49 a	42.50 b
Proximal to remnant without road crossing	68.29 a	37.50 b

Table 26: Significant relationships between mammal taxa and exurban garden types and artefacts within the Kingborough (light grey columns) and South Arm (dark grey columns) regions. P/A = species recorded at a site during at least one spotlight survey (distribution); F = frequency of occurrence within spotlight surveys; LO = species reported by landowner (distribution).

	Total species richness	Native species richness	*B. gaimardi* F	*I. obesulus* P/A	*I. obesulus* LO	*O. cuniculus* P/A	*O. cuniculus* F	*P. gunnii* F	*P. gunnii* LO	*P. peregrinus* P/A	European *Rattus* spp. LO	*T. billardierii* LO	*T. vulpecula* P/A	Total species richness	Native species richness	*B. gaimardi* P/A	*B. gaimardi* F	*O. cuniculus* F	*P. gunnii* P/A	*P. gunnii* F	*P. tridactylus* P/A
Chicken yard				+ ve																	
Lawn			- ve							- ve									+ ve	+ ve	
Native garden							- ve														
Min. input shrub garden									+ ve			- ve				+ ve	+ ve				
Wind break						+ ve						- ve		+ ve	+ ve			+ ve	+ ve		
Water: dam and / or river								+ ve					- ve		+ ve			+ ve			
Orchard	- ve	- ve			+ ve								- ve								
Productive garden											+ ve			+ ve	- ve						- ve

Table 27: Significant relationships between mammal taxa and exurban land cover types, substrate, and property size and location. P/A = species recorded at a site during at least one spotlight survey (distribution); F = frequency of occurrence within spotlight surveys; LO = species reported by landowner (distribution).

	> 25 % exurban forest	> 50 % exurban forest	> 25 % forest	> 50 % forest	Modified forest	Tussocky paddock	Grassy woodland	Habitat richness	Pasture paddock	Mudstone	Undefined soils	Igneous	Housing density	Property size	Proportion of forest in surrounds	Adjacent remnant without road	< 250 m from wildlands remnant
Kingborough																	
Total species richness (SS)		- ve			+ ve		+ ve		+ ve								
Native species richness (SS)		- ve			+ ve		+ ve				- ve						
B. gaimardi $^{P/A}$					- ve												
B. gaimardi ^{F}							+ ve										
B. gaimardi ^{LO}	- ve																
I. obesulus $^{P/A}$					+ ve			+ ve									
I. obesulus ^{F}					+ ve			+ ve									
I. obesulus ^{LO}								+ ve									
M. rufogriseus ^{F}							+ ve										
M. rufogriseus ^{LO}	+ ve		+ ve				+ ve										
O. cuniculus $^{P/A}$			- ve	- ve											- ve		
O. cuniculus ^{F}	- ve														- ve		
P. gunnii $^{P/A}$									+ ve								

	> 25 % exurban forest	> 50 % exurban forest	> 25 % forest	> 50 % forest	Modified forest	Tussocky paddock	Grassy woodland	Habitat richness	Pasture paddock	Mudstone	Undefined soils	Igneous	Housing density	Property size	Proportion of forest in surrounds	Adjacent remnant without road	< 250 m from wildlands remnant
P. gunnii [F]										+ ve				+ ve			
P. gunnii [LO]																	
P. tridactylus [P/A]					+ ve		+ ve										
P. tridactylus [F]					+ ve												
P. tridactylus [LO]												+ ve					
P. peregrinus [P/A]	+ ve		+ ve	+ ve													
P. peregrinus [LO]					+ ve												
European *Rattus* spp. [LO]	- ve																
T. billardierii [F]			+ ve										- ve		+ ve		
T. billardierii [LO]														- ve			
T. vulpecula [P/A]													- ve				
T. vulpecula [F]			+ ve				+ ve						- ve	+ ve			
South Arm																	
Total species richness (SS)								+ ve									
I. obesulus [F]													+ ve				
I. obesulus [P/A]													+ ve				
O. cuniculus [P/A]								+ ve									
O. cuniculus [F]	- ve		- ve	- ve				+ ve	+ ve						- ve		
P. gunnii [P/A]		- ve	- ve	- ve				+ ve	+ ve								
P. gunnii [F]							+ ve	+ ve	+ ve	+ ve							- ve

T. vulpecula [F]	European *Rattus* spp. [LO]	*P. peregrinus* [LO]	*P. gunnii* [LO]	
				> 25 % exurban forest
				> 50 % exurban forest
+ ve				> 25 % forest
+ ve				> 50 % forest
				Modified forest
		- ve		Tussocky paddock
				Grassy woodland
			+ ve	Habitat richness
	- ve			Pasture paddock
				Mudstone
				Undefined soils
				Igneous
				Housing density
				Property size
				Proportion of forest in surrounds
				Adjacent remnant without road
				< 250 m from wildlands remnant

European rabbits and rats, and inconsistent for the Tasmanian bettong. Overall, properties that had treed habitats with open understoreys (modified forest and grassy woodland), and some pasture, had significantly higher numbers of species than properties predominately covered by exurban forest. *P. gunnii* and *P. tridactylus* were significantly positively associated with properties with mudstone and igneous substrates respectively. Consequently, undefined soils were significantly negatively related to total native species richness. *T. billardierii* and *T. vulpecula* were recorded most frequently in areas with relatively low housing densities, and *T. billardierii* was also most frequently observed in the most forested parts of the exurban landscape. Remnant proximity was not significantly related to any mammal taxa in Kingborough.

South Arm

Species displayed similar habitat associations in South Arm. Properties with habitat mosaics had high species richness, mostly due to the presence of *O. cuniculus* and *P. gunnii*, which were both associated with the least forested areas of the landscape. In contrast to Kingborough, one species, *I. obesulus*, was significantly positively associated with housing density.

Discussion

The present study has found that flightless mammalian species have non-uniform responses to exurbanisation; that one threatened native species was uniformly more frequently recorded in exurbia than in wildlands; that the spatial arrangement of

private housing parcels and wildland remnants within exurban regions has a significant effect on the capacity of species to persist in the exurban landscape; that species with large home range sizes are disadvantaged when the area of adjacent wildland remnants is critically reduced by placing homes within forests, rather than at the edge; that, within exurbia, species habitat preferences are largely the same as their preferences in non-urban landscapes; that one native species is found most frequently in exurban areas where houses are clustered, while two other species are more frequent where houses are dispersed.

Consistent with previous studies, spotlighting under-sampled very small bodied species (Catling *et al.*, 1997). This limits the conclusions that can be drawn from the correlations between EAR and species traits. However, the landowner observations, which were strongly consistent in comparison to the assemblages of species recorded by spotlight, can be used to validate the EAR correlations to some degree. The significant relationship between small body size and exurban adaptability in South Arm is consistent with a number of studies that have shown that small body size confers an advantage against contemporary extinction threats (Gaston and Blackburn, 1995; Smith and Quin, 1996; Jennings *et al.*, 1998; Cardillo and Bromham, 2001; Cox *et al.*, 2003; Wilson *et al.*, 2003; Lomolino and Perault, 2007; da Silva and Pontes, 2008). The paucity (compared to Kingborough) of landowner reports of small-bodied species such as *A. swainsonii* and *R. lutreolus* in South Arm does not necessarily invalidate the influence of body mass on exurban adaptability, as both species have restricted distributions in dry forests (Rounsevell *et al.*, 1991). The absence of the large-bodied common wombat in South Arm is also consistent with

the body mass correlation with EAR. Nonetheless, the negative influence of home range was more strongly evident within the assemblage of species recorded by spotlight in South Arm, is not invalidated by landowner reports, and was most strikingly evident in the non-uniform responses of macropods and potoroids to exurban regions.

P. tridactylus and *M. rufogriseus* have been found to occur predominately in forested areas greater than 20 ha (Bennett, 1990). *P. tridactylus* require in excess of 1550 ha of habitat in order to maintain a viable population (Kitchener, 1973), which, in macropods and potoroids, constitutes 200-300 individuals (Main and Yadav, 1971). Purely in terms of native forest cover, there is sufficient natural habitat remaining in South Arm to maintain viable potoroid and macropod populations. However, only 800 ha of undeveloped wildland remnants remain. Thus, the division of forest into exurban properties can change a forested area's suitability as potoroid and wallaby habitat. Exurban areas may function as population sinks for wildland potoroid and macropod populations, with this process being most apparent in areas where migration of source individuals from extensive wildlands is limited, such as in peninsular South Arm. This contrasts with species that can breed within exurbia, which have been found to source populations in adjacent, less productive, wildland habitat (Hansen and Rotella, 2002).

The negative relationship between landowner reports of *T. billardierii* and property size seemingly contrasts with the greater number of spotlighting observations of the species where houses were dispersed. However, it is most likely to be an indication that exurban residents mostly observe wildlife in the immediate

vicinity of their home (Harrison, 1998), and thus are less likely to report species that are housing shy.

In terms of responses to exurban habitats, macropods were positively associated with forest cover at the local and landscape level, which is consistent with their requirements for diurnal shelter (Johnson, 1980; Vernes *et al.*, 1995).

Both *P. tridactylus* and *B. gaimardi* are largely mycophagous (Bennett and Baxter, 1989; Claridge and May, 1994). The inconsistent relationships between *B. gaimardi* and measures of forest presence and cover in Kingborough may be a consequence of unmeasured variation in the abundance of hypogeal fungi (Taylor, 1993a). Both species predominantly occur in areas of low soil fertility (Taylor, 1993a; Johnson, 1994b; Claridge and Barry, 2000), seemingly because low fertility promotes the extent of mycorrhizal development (Johnson, 1994a). Thus, the negative relationship between *P. tridactylus* and productive gardens, and between *B. gaimardi* and lawns, may indicate that fertilisers being applied to some anthropogenic habitats are increasing levels of soil fertility beyond the immediate area of application.

The significant relationship between EAR and fecundity in Kingborough may indicate that in exurban regions where access to extensive wildlands is not limiting, the most significant determinant of species assemblages are demographic pressures (Owens and Bennett, 2000), because fecund species are capable of maintaining viable populations despite high levels of mortality, thus lessening the chance of stochastic extinction (Pimm *et al.*, 1988). It has been found that reproductive capacity played a significant role in contemporary Australian mammal extinctions

(Smith and Quin, 1996; Cardillo, 2003; Johnson, 2006) and that slow reproductive rates were more influential than body mass in the Late Quaternary global 'megafauna' extinctions (Johnson, 2002; Johnson, 2006).

The relationship between fecundity and EAR in Kingborough was strongly influenced by the relative abundances of two medium sized species, the European rabbit, and the threatened Eastern barred bandicoot. The positive relationship between European rabbits and exurbia is consistent with observations of native cottontail rabbits in exurban Arizona (Bock et al., 2006a), but the species flourish in exurbia for contrasting reasons. Cottontail rabbits seemingly benefit from the increased vegetation complexity that exurbanisation creates in semi-arid Arizonan grasslands, while European rabbits were most abundant in cleared exurban areas of Hobart. Similarly, the negative relationship between *P. gunnii* and exurban forest cover is consistent with their historical response to land clearance in Tasmania (Hocking, 1990) and the reliance of *Perameles* species on open areas for nocturnal foraging (Chambers and Dickman, 2002). A comparative study of exurbia and non-urban landscapes with similar habitat mosaics is needed to further investigate the effects of exurbanisation on fecund species independent of habitat heterogeneity.

The positive relationship between *P. gunnii* and exurban dams and / or rivers could be a consequence of the correlation between water and habitat richness, but is consistent with previously documented associations between bandicoots and swamps, riparian habitats, and dams, in non-urban environments (Opie *et al.*, 1990; Robinson *et al.*, 1991; Alessio, 2000). Riparian habitats, including dams, may be associated with moist soils, which might be selected by bandicoots due to high

densities of prey. Alternatively, moist soils may be the most energetically efficient soils in which to dig. However, relationships between peramelids and substrate density are inconsistent with this hypothesis. The Tertiary sediments that *P. gunnii* was associated with in the current study are typically more dense than the undefined soils that *Perameles* species preferentially forage in elsewhere (Dufty, 1991; Chambers and Dickman, 2002), but consistent with the compacted soils that bandicoots were associated with in another study (Braithwaite and Gullan, 1978). Spatial variation in bandicoot-soil associations may be reflecting variation in unmeasured habitat characteristics.

In suburban Brisbane, the majority of residents that live adjacent to forests known to be inhabited by *Isoodon macrourus* were found to be unaware that bandicoots lived in those adjacent forests (FitzGibbon and Jones, 2006), indicating a spatial disparity between human and bandicoot habitat. However, in the present study, spotlight observations under-estimated the exurban distribution of *I. obesulus* and *P. tridactylus* compared to landowner observations. This is an indication that *I. obesulus* and *P. tridactylus* are diurnally active within exurbia. This is inconsistent with the disproportionately high levels of nocturnal activity exhibited by other species of mammal within exurban landscapes (Vogel, 1989; Harrison, 1997), but is not uncharacteristic behaviour for *I. obesulus* and *P. tridactylus*, which are partially diurnal in natural habitats (Heinsohn, 1966; Seebeck and Rose, 1989; Lobert, 1990). Many landowners, however, were unaware that *B. gaimardi* utilised their property, indicating a temporal disparity between bettong and human activity levels. Within mammal species, an individual's diurnal activity level may be proportionate to the

local level of disturbance. *I. obesulus* ostensibly perceive little disturbance within the South Arm area given their positive relationship with housing density.

The non-uniform distribution of *I. obesulus* between exurban regions may reflect higher densities of their fungal food species in regions with warmer temperatures (Claridge and Barry, 2000). Increased food availability may also be the reason clustered housing benefited *I. obesulus*. Southern brown bandicoots in South Arm were observed opportunistically foraging on non-natural food provided by landowners for pet cats, dogs, and chickens. This behaviour was not observed within Kingborough and, thus, the effects of housing density on brown bandicoots may vary spatially in accordance with the tendency of local individuals to scavenge anthropogenic food.

The high numbers of *T. vulpecula* recorded in exurbia are consistent with their wide distribution across non-natural habitats within Tasmania (Rounsevell *et al.*, 1991) and their high level of persistence in urban environments (van der Ree and McCarthy, 2005), which has occasionally resulted in the species receiving pest status among residents (Matthews *et al.*, 2004). However, *T. vulpecula* was significantly less frequently recorded in exurban Kingborough than in wildlands, and was less frequent in areas of Kingborough with clustered housing. Buildings contain the most regularly visited den sites of *T. vulpecula* within urban environments (Statham and Statham, 1997). Thus, housing associated disturbances operating within exurban Kingborough may force local possums to establish a disproportionate number of dens in tree cavities, which is supported by their positive association with exurban properties with high levels of tree cover. The disproportionately low abundance of *T.*

vulpecula in Kingborough is seemingly due to a greater abundance of trees hollows in the forests of South Arm. Thus, the implications of exurbanisation on *T. vulpecula* may vary temporally in accordance with tree demography, and may be ameliorated by nest box provision (Lindenmayer *et al.*, 2003), or exacerbated by firewood collection.

P. peregrinus was not significantly affected by exurbanisation, which is consistent with its capacity to persist in fragmented landscapes (Bennett, 1990) and the response of other arboreal foliovores to fragmentation (Deacon and Mac Nally, 1998). *P. peregrinus* is less dependent than *T. vulpecula* on tree hollows because it builds and nests in dreys. However, *Pseudocheirus occidentalis* is disproportionately dependent on tree hollows in forests with sparse understoreys (Jones *et al.*, 1994). It is therefore possible that widespread understorey clearance within exurban forest could reduce exurban populations of *P. peregrinus*.

Conclusion

From a planning perspective, clustering housing parcels at suburban densities in isolated peninsula landscapes will result in the loss of less natural habitat than dispersed housing (Gonzalez-Abraham *et al.*, 2007) and facilitate the persistence of mammal species with large home range requirements in urban landscapes isolated from extensive wildlands. In exurban Hobart, this might result in fewer *T. vulpecula* and *T. billardierii* in the immediate vicinity of houses. In other regions, clustered exurban developments do not necessarily disadvantage wildlife relative to dispersed exurban development (Odell and Knight, 2001; Lenth *et al.*, 2006). Further research

is needed to identify the housing-associated disturbance factors that cause *T. vulpecula* and *T. billardierii* to be housing shy within certain exurban regions, and to contrast these with disturbance levels in other urban areas where *T. vulpecula*, in particular, is more common. Human activity can be a significant disturbance factor in itself, but domestic mesopredators can compound human disturbance (Lenth *et al.*, 2008) and are abundant around exurban houses (Odell and Knight, 2001; Maestas *et al.*, 2003). Thus, cats and dogs will be explored as a housing-associated disturbance factor in the next chapter.

Interactions between exurban people, pets and wildlife

Introduction

Exurban residents love nature. In addition to the amenity of space (both within and around homes), exurban residents have been found to place a high value on living in proximity to nature, particularly forested landscapes (Kaplan and Austin, 2004). Compared to urban residents, exurbanites (at least on a local basis): place greater value on native mesopredator populations (Harrison, 1998); are less concerned about the threat of snakes and spiders around their home (Woolcott Research, 2002); are more passionate and skilled bird watchers, with a greater understanding of seasonal and temporal variation in bird activity (Clergeau *et al.*, 2001); are more likely to believe in the benefits of, and implement, wildlife conservation measures on their properties (Woolcott Research, 2002); tend to agree with the removal of harmful introduced predators (Woolcott Research, 2002); appreciate natural and native, rather than exotic, gardens (Woolcott Research, 2002); and view threats to the environment with greater levels of concern (Woolcott Research, 2002).

Some exurbanite activities and land management practices may inadvertently affect wildlife. Species exhibit varied responses to exurban grazing regimes (Bock *et al.*, 2006c; Bock *et al.*, 2006a; Bock *et al.*, 2008) and may be similarly affected by mowing or slashing. Tidying or collection of dead wood may negatively affect reptiles

(Garden *et al.*, 2007) and fertilising lawns or paddocks may increase soil fertility at forest edges, potentially leading to increases in foliage density and arboreal foliophiles (Harding and Gomez, 2006).

In other cases, nature lovers may express their ideals through deliberate attempts to promote local biodiversity. The provision of supplementary food to wildlife is largely regarded as a positive action by exurban residents (Clergeau *et al.*, 2001; Woolcott Research, 2002; Lepczyk *et al.*, 2004) and, within suburban areas, has consistently been found to increase local abundances of birds (Parsons *et al.*, 2003; Daniels and Kirkpatrick, 2006b; Fuller *et al.*, 2008). Urban landowners also attempt to create wildlife habitat through means such as plant selection and artificial nest site provision, with varying levels of success (Gaston *et al.*, 2005).

Some activities practiced by exurbanites are an attempt to exterminate components of nature, rather than encourage them. At the rural end of the exurban spectrum, biocide application is significantly more prevalent than it is in suburban and urban developments (Lepczyk *et al.*, 2004). Exurban residents in New South Wales, however, are less likely to use pesticides on their land than urban residents (Woolcott Research, 2002). Such behavioural inconsistencies may be a result of three things: spatially heterogeneous exurbanite sociology, which may result from the juxtaposition of commuters and small farm operators; non-uniform appreciation of the manifold aspects of nature, which is expressed by urban residents in their varied appreciation of wild species (Clergeau *et al.*, 2001; Bjerke *et al.*, 2003; Tisdell *et al.*, 2005; FitzGibbon and Jones, 2006); and / or inconsistencies between human opinion and behaviour (Zagorski *et al.*, 2004; McCleery *et al.*, 2006).

Pet cats *Felis catus* and dogs *Canis familiaris familiaris* are abundant in exurbia and concentrate most of their activity around houses (Odell and Knight, 2001; Maestas *et al.*, 2003), as they also do in more urbanised (Kays and DeWan, 2004) and less urbanised (George, 1974; Meek, 1999) landscapes (although large movements of several km can occur in dogs with a propensity to wander (Coman and Robinson, 1989; Meek, 1999)). Consequently, the number of wild prey caught by urban pet cats has been shown to be negatively related to the distance of their owners house from the forest edge (Barratt, 1998). Thus, exurban populations of domestic mesopredators may be particularly detrimental to wildlife, because they frequently live within natural habitats. Potentially significant, but largely unquantified consequences of exurban populations of domestic mesopredators are lethal predation, interspecific competition, disease transmission, and non-lethal harassment of native wildlife.

Most of the mammalian species that occur within exurban Hobart (or at least congenerics of) have been reported as prey to either domestic or free-ranging *F. catus* and / or *C. f. familiaris* (Schlager, 1981; Triggs *et al.*, 1984; Delroy *et al.*, 1986; Catling, 1988; Lenghaus *et al.*, 1990; Dufty, 1994b; Barratt, 1997b; Paltridge *et al.*, 1997; Jones *et al.*, 2003) [1]. Similarly, *F. catus* is known to prey on many native birds and various other life forms (Barratt, 1997b; van Heezik *et al.*, 2010).

[1] Species directly reported as prey are: *Antechinus* spp., *Dasyurus maculatus*, *Dasyurus viverrinus*, *Hydromys chrysogaster*, *Isoodon obesulus*, *Macropus rufogriseus*, micro chiropterans, *Perameles gunnii*, *Petaurus breviceps*, *Potorous tridactylus*, *Pseudocheirus peregrinus*, *Rattus lutreolus*, *Sarcophilus laniarius*, *Tachyglossus aculeatus*, *Trichosurus vulpecula*, *Vombatus ursinus*, and

The provision of supplementary food unburdens domestic predators from the constraints of low prey densities, particularly during the winter months, a time when wild *F. catus* can starve to death (Jones, 1977). Domestic *F. catus* kill wildlife regardless of the need for food (Toner, 1956; Leyhausen, 1979) and obtain between 15 and 90 % of their total food intake from wild prey (Liberg, 1984). Although this is only a quarter of the wild prey intake of their self sufficient counterparts (Liberg, 1984), a domestic predator selectively preying upon a particular species could potentially result in its extirpation. However, *F. catus* appears to be largely opportunistic, killing prey in proportion to their local abundance (Coman and Brunner, 1972; Barratt, 1997b), with the most evident discriminations being the age, size and mobility of prey (Errington, 1936; Jones, 1977; Liberg, 1984; Childs, 1986). Domestic dogs are also potentially opportunistic, like the congeneric dingo *C. f .dingo* (Newsome and Coman, 1989). If domestic mesopredators are opportunistic, their predation may have little effect on the composition of urban faunal assemblages, despite killing numerous individuals.

There is ostensibly little interspecific competition between *F. catus* and the Tasmanian native quoll *D. viverrinus*, as they have coexisted in Tasmania for 200 hundred years (Johnson, 2006) and *D. viverrinus* is largely insectivorous (Blackhall, 1980). Because *F. catus* is a hyper-carnivore (Parmalee, 1953; Eberhard, 1954; Catling, 1988; Paltridge *et al.*, 1997), it has more dietary overlap with *D. maculatus*,

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the introduced *Mus musculus*, *Oryctolagus cuniculus* and *Rattus rattus*. Reports of congenerics or similarly sized family members only: *Bettongia gaimardi* and *Thylogale billardierii*, which are extinct on the Australian mainland where most of the cited studies were carried out.

particularly smaller females (Belcher, 1995; Jones and Barmuta, 1998; Glen and Dickman, 2006; Dawson *et al.*, 2007). Scavenging of carcasses by domestic predators could be deleterious to *S. laniarius* populations. The scavenging dingo evidently played a significant role in the extinction of *S. laniarius* from the Australian mainland (Jones *et al.*, 2003; Johnson, 2006).

Domestic cats are a source of the potentially fatal *Toxoplasmosis gondii* (Obendorf and Munday, 1990), which was found to occur in > 10 % of *P. gunnii* in Hamilton, Victoria (Lenghaus *et al.*, 1990). Domestic dogs are also vectors of parasites and disease (Stevenson and Hughes, 1988). In particular, wild carnivores in protected areas adjacent to human settlement are vulnerable to lethal infections of canine distemper (Alexander and Appel, 1994; Daszak *et al.*, 2000; Gowtage-Sequeira *et al.*, 2009; Megid *et al.*, 2010).

Although cat gender, weight, breed purity, age of neutering and the number of feeds per day have all been found to have no influence on the total annual amount of prey caught per cat (Barratt, 1998), pet management may be an effective way to lessen the impact of domestic pets. The effects of cats wearing bells are inconsistent (Barratt, 1998; Ruxton *et al.*, 2002; Woods *et al.*, 2003), thus, more definitive measures are needed. Between 61 and 66 % of suburban domestic cats are unrestrained at night (Trueman, 1991; Reark Research, 1994) and there is a positive relationship between the number of nights a cat spends outside and the total number of prey caught per annum (Barratt, 1998; Woods *et al.*, 2003). However, total predation has been shown to be largely the result of diurnal predation (49.8 %), with nocturnal and crepuscular predation yielding lesser proportions (30.1 and 20.1

%) (George, 1974), despite cats having disproportionately large nocturnal ranges (Barratt, 1997a).

This chapter will use a printed survey to document the opinions of exurban residents on variety of nature-related issues, to quantify both their participation in activities that may affect wildlife, and the numbers, prey, and activity levels of exurban domestic mesopredators. The actions of landowners and their pets will be tested against observations (Chapter 4) and reports of mammalian fauna. The following questions are addressed: (1) Is exurban Hobart populated by people with homogeneous land management practices and nature-related opinions, or are there distinguishable groups of exurbanites? (2) If exurbia has distinguishable assemblages of people, are they distributed randomly across exurbia or are they associated with certain landscape or property characteristics? (3) Are differences in exurbanite characteristics, property choice and / or land management reflected in the distribution of wild mammals? (4) What kinds of wildlife are being preyed upon by domestic predators? (5) Does pet ownership and activity have any effect on the distribution and frequency of wild mammals in exurbia?

Methods

Landowner questionnaire – survey instrument

The survey instrument constituted a 16 page paper booklet with two sections (Appendix P). Section 1 included 13 questions related to landowner observations of wildlife, landowner activities, and landowner attitudes to wildlife. Section 2 was comprised of questions relating to socioeconomic status and respondent

identification, in case any responses needed clarification and so survey responses could be tested against property variables. Some questions were included for purposes other than this thesis and are not reported here. All the questions utilised in the current study are outlined below, with the question numbers referring to the question number in the survey instrument.

Section 1

Question 1 – Landowner observations / species distributions

Question 1 comprised a list of the common names of 36 animal species. The mammalian species included in the list have already been presented in Table 19. The remainder of the species on the list were (with Latin names listed here for reference): masked owl *Tyto novaehollandiae*, southern boobook *Ninox novaeseelandiae*, tawny frogmouth *Podargus strigoides*, Australian owlet-nightjar *Aegotheles cristatus*, tiger snake *Notechis scutatus*, copperhead snake *Austrelaps superbus*, white-lipped snake *Drysdalia coronoides*, blue-tongue lizard *Tiliqua nigrolutea*, mountain dragon *Rankinia diemensis*.

Exurban landowners (EL) were asked to indicate, by ticking an adjacent box, which of the species on the list they were certain inhabited their property.

Question 3 – Species likeability / happiness to share property with

Question two constituted a list of 24 animal species or groups: bandicoots; bats; blue tongue lizard; bumblebees; butterflies; caterpillars; cockatoos; common blackbird; common brushtail possum; common ringtail possum; European rabbit; European

rats; frogs; house mouse; house sparrow; jackjumper ant; pygmy possums; quolls; raptors; small native birds; snakes; spiders; Tasmanian devil; and wallabies.

EL were asked to indicate how happy they were to share their property with each individual species or group, even if they thought that the species did not actually inhabit their property. EL were asked to express their happiness by ticking the appropriate box within a five-point Likert scale ranging from "very unhappy" to "very happy", with a sixth option of "do not know".

Question 4 – Troublesome species

Question three constituted a list of 13 animal species or groups previously reported as troublesome or undesirable (Davies *et al.*, 2004; FitzGibbon and Jones, 2006) or considered to potentially be so. They were: bandicoots; common brushtail possum; common ringtail possum; European rabbit; feral cat; introduced birds; jackjumper ant; neighbours domestic cat; neighbours domestic dog; neighbours domestic stock; noisy miner; snakes; and wallabies.

EL were asked to state how often they experienced problems with each of these species or groups on their properties by ticking the appropriate box corresponding to the options of: daily; weekly; monthly; seldom; and never; with a sixth option for animals that were "not present" on their property. Additional space was available for respondents to add troublesome species that were not on the list.

Question 5 – Hypothetically over-abundant native animals

Following on from troublesome species, question four raised the scenario of native animals potentially becoming troublesome as a result of their over-abundance in certain urban environments (Matthews *et al.*, 2004; Temby, 2004).

EL were asked to state their level of agreement with possible conclusions to the following sentence fragment: *"Over-abundant native animals should be . . ."*

The six options for conclusion were: humanely captured and relocated; controlled by residents; controlled and monitored by local councils; tolerated; controlled only if they pose a threat to other native animals or to people; treasured, they may be abundant in some places, but they may be declining overall.

EL indicated their level of agreement with each of the conclusions by ticking the appropriate box within a five-point Likert scale ranging from "strongly disagree" to "strongly agree", with a sixth option of "no opinion".

Question 6 – Exotic species within exurbia

Question five was comprised of a list of four statements regarding introduced species of wildlife. EL were asked to indicate their level of agreement with each statement by ticking the appropriate box within a five-point Likert scale ranging from "strongly disagree" to "strongly agree", with a sixth option of "no opinion".

The four statements were: Introduced species should be controlled if they out-compete native species; Having any type of animal on my property is better than none at all; All sentient beings deserve to flourish regardless of origin; Introduced species have no place here and should be exterminated.

Question 7 – Landowner activities

Question six comprised a list of 17 nature or land management related activities: Planting / maintaining vegetation with the intent of creating wildlife habitat; Planting / maintaining vegetation for other reasons (e.g. vegetables or cut flowers); Watching wildlife; Watching wildlife in areas away from your home and property (e.g. national parks); Feeding birds; Feeding wildlife other than birds; Hunting and / or shooting animals; Watching television programs about nature; Reading books about nature; Pesticide application; Herbicide application; Fertiliser application; Trapping and relocating brushtail possums; Trapping and relocating native animals other than brushtail possums; Releasing animals captured or rescued from other areas; Collecting firewood; Paying someone else to maintain property / garden.

EL were asked to indicate how often they (or people with their permission) participated in each of the activities (on their property only, unless otherwise stated) by ticking the appropriate box corresponding to the options of: daily; weekly; monthly; seldom; and never.

Question 8 – Domestic mesopredators

EL were asked to indicate if the had one or more pet cats and / or dogs on their property. Participants were asked to indicate if they kept pet dogs and / or cats on their property. Pet owners were asked to state the number of each species that they owned and to state how frequently their pet(s): chased and harassed wildlife; captured wildlife; were outside and unrestrained during the daytime; and were outside and unrestrained during the night. Frequency intervals were “daily”, “weekly”, “monthly”, “seldom”, “never” and a 6th option of “can’t be sure”.

Respondents with dogs were asked to note the breed of their dog(s) and the size of the dog within the size categories (measured from shoulder height to ground): small < 30 cm, medium 30 – 60 cm and large > 60 cm. Respondents whose pets had caught wildlife were asked to list the species caught and to be as specific as possible when doing so.

Question 9 – Exurban trees

Using a five-point Likert scale ranging from “strongly disagree” to “strongly agree”, and including a sixth option of “no opinion”, EL were asked to indicate their level of agreement with each of 15 statements regarding trees growing in close proximity (25 m) to their homes, regardless of if they had trees close to their home or not. EL were instructed to consider any woody plant ≥ 8 m in height as a tree.

The tree statements were: Trees harbour nuisance animals and so I don't like them near my home; Falling limbs are too dangerous to have trees near the home; Trees are a symbol of wealth and prosperity; Trees increase real estate prices; Trees provide vital habitat for native animals; Trees give me shelter and privacy; Trees are too hard to control; Trees create unwanted mess; Trees cast too much shade; Trees provide useful shade from summer heat; Trees are too serious a fire hazard to have near the home; Trees are good for the environment; Trees reduce home security because they provide cover for burglars; Tree roots damage drains and drives (infrastructure); Trees are a hassle because their leaves block roof guttering.

Question 10 – General comments on exurban nature conservation

On a five-point Likert scale ranging from "strongly disagree" to "strongly agree", and including a sixth option of "no opinion", EL were asked to indicate their level of agreement with each of five general statements: People living in and near the bush should have minimal impact on native animals [2]; I wish it was easier to clear bush to create more paddocks for stock; Feeding wild animals is fine in moderation; Dogs are a threat to wildlife in the urban fringe; Cats are a threat to wildlife in the urban fringe.

Question 11 – Willingness to act

On a three-point scale from "No" to "Maybe" to "Yes", EL were asked to indicate if they would be willing to: pay a conservation agency to undertake nature conservation projects on your land; allow a conservation agency to undertake conservation projects on your land if you were compensated adequately; allow a commercial agency to harvest trees on your property if you were compensated adequately; change your land management practices if you were informed of potentially better practices for wildlife.

Question 12 – Examining the exurban ideal

EL were presented with 15 statements relating to potentially desirable aspects of exurban living and asked to indicate how important each factor was in determining if

[2] Bush and bushland are Australian colloquial terms for natural vegetation

somewhere was a nice place to live (NPTL), on a four-point scale consisting of: “not important at all”, “slightly important”, “reasonably important” and “very important”.

The NPTL statements factors were: A place that has the potential to provide me with a source of income; A place that is a haven for wildlife; A place that has space for children to play; A place that has space for domestic animals; A place where I can harvest firewood; A place where I can grow fruit and vegetables; A place where I can undertake passive recreation (e.g. gardening, camping and / or hiking); A place where I can undertake active recreation (e.g. motorcycle riding); A place where I can be close to nature and wildlife; A place that is close to the city; An area that has cheap real estate; A place that has a romantic, country-feel; A place with nice environmental conditions (temperature, rainfall); A place with lots of natural bushland nearby; Being surrounded by like-minded neighbours.

Question 13 – Hypothetical relocation

EL were asked to consider the scenario of relocating to another home, and asked to indicate on a five-point scale from “Very unlikely” to “Very likely” how probable it is that their new home would be within a given level of urbanisation: urban / city; suburban; elsewhere in exurbia; rural / agricultural; remote bushland.

Section 2

Within section 2, EL were asked to complete a small number of questions documenting housing tenure, total household income; the education level of the most educated person in the home; the age of each resident.

Data collection

On the 11th of May 2007, one survey booklet and a pre-stamped, self-addressed envelope were sent to each of the 89 participating exurban properties. The package was either addressed to both property owners, or to the person on the property with whom most prior correspondence had occurred. Regardless, the survey instructions stated: "*It does not matter who completes this survey as long as they are resident on the participating property. You can even have multiple residents collaborate in the completion of the survey. In cases where more than one person is helping complete the survey, you have three options: you can come to a consensus on your answers; you can mark two or more boxes for the differing opinions; or you can elect a household representative, preferably the person with the most influence on your property's management, to answer the questions. The consensus option is probably the best option as it is likely that this situation of compromise is what occurs in regards to your properties management anyway.*"

Participants were asked to complete and return the survey by mail before 22nd of June, 2007. Participants that had not returned a completed survey by the 31st of July, 2007, were called by telephone and reminded of the survey. No further reminders were given after this, unless the participants themselves mentioned the survey.

Data coding and analysis

In order to test variation in the survey responses of individuals, landowner responses to questions two through twelve in section one of the survey instrument were collectively ordinated using non-metric multi-dimensional scaling with the default

options in DECODA (Minchin, 2001). Responses in the categories of “do not know”, “not present”, “can’t be sure” and “no opinion” were treated as missing data. Responses of landowners that needed assistance with species identification and were supplied with photos were excluded from the results of Q3 because of potential bias associated with information provision (Ajzen *et al.*, 1996; Spash, 2002; Tisdell *et al.*, 2005). The ordination solution with the lowest number of dimensions and a stress value < 0.20 was accepted. Cluster analysis of ordination scores was used to establish the number of groups of exurbanites, which were tested for difference by paired analyses of similarity (ANOSIM) using Bray-Curtis similarity and 10 000 permutations in DECODA (Minchin, 2001).

Variation in the mean response values of each group for each of the questions within the ordination set were tested using One-Way ANOVA and Tukey’s Comparison Test (with a family error of five) for comparisons between continuous and class variables, and Pearson’s Chi-squared and Fishers Exact Probability Test for comparisons between class variables[3]. The same procedures were used to test: variation in the frequencies and distributions of mammalian taxa on the properties on each class of people; variation in property location and composition of each class of people; socioeconomic and demographic variation between the exurbanite classes; comparative levels of predation between cats and dogs between and within

[3] Response values were coded ordinally on a scale of the same number of values as there were potential answers to the question (excluding “do not know”, “no opinion” etc.). In all cases a response value of 1 corresponds to the lowest possible level of agreement, lowest level of happiness, lowest frequency of activity etc.

regions, and between cats or dogs between regions; and effects of livestock, domestic mesopredator presence and activity, and potentially influential human activities, on the frequency and distribution of mammalian taxa, independent of exurbanite groups.

Property habitat and location variables are the same as those used in Chapter 4. Presence and type of livestock were assessed in the field. The potentially influential human activities tested against flightless mammals were a subjective selection of the activities listed in survey question number six. The activities tested were: Planting / maintaining vegetation with the intent of creating wildlife habitat; Planting / maintaining vegetation for other reasons (e.g. vegetables or cut flowers); Feeding birds; Feeding wildlife other than birds; Hunting and / or shooting animals; Pesticide application; Herbicide application; Fertiliser application; Trapping and relocating brushtail possums; Trapping and relocating native animals other than brushtail possums; Releasing animals captured or rescued from other areas; Collecting firewood.

In all tests, $P < 0.05$ was taken as the level of significance.

Results

A total of 73 participants completed the survey (82 % response rate). Thirty-three respondents were from Kingborough (80.49 %) and 40 were from South Arm (83.33 %). All respondents had resided on their current property for at least 2 years.

Groups of exurban people

Cluster analysis of ordination scores revealed four groups of people (Figure 16). The four groups varied significantly in their responses to numerous questions (Appendix Q), but particularly in their expressed levels of happiness regarding sharing their property with species of wildlife (Figure 14) and in their opinions on trees close to their home (Figure 15).

Group 1 – Biophiles

Helen: "We feel that we are just custodians of the land and hope to be sympathetic in our dealings with the environment".

Group 1, the biophiles, displayed high levels of love for both plants and animals. The biophiles had the highest mean 'happy to share property' scores for every native animal species or group and believed bush inhabitants should have minimal impact on native animals. They were tolerant of native species even if they were considered over-abundant, and were intolerant of exotic species that might out-compete natives. Biophiles frequently participated in wildlife watching on and away from their homes and actively encouraged wildlife through habitat planting and, to a lesser extent, the provision of supplementary food. Biophiles were pragmatic in their opinions of trees, valuing them as wildlife habitat, as creators of shade and privacy, and for their influence on realty value. Biophiles were strongly inclined to continue living within exurbia rather than move to a different level of urbanisation, and valued the exurban landscape for the wildlife, the romanticism of the countryside, the proximity to nature, the native forests, and the fellow biophiles.

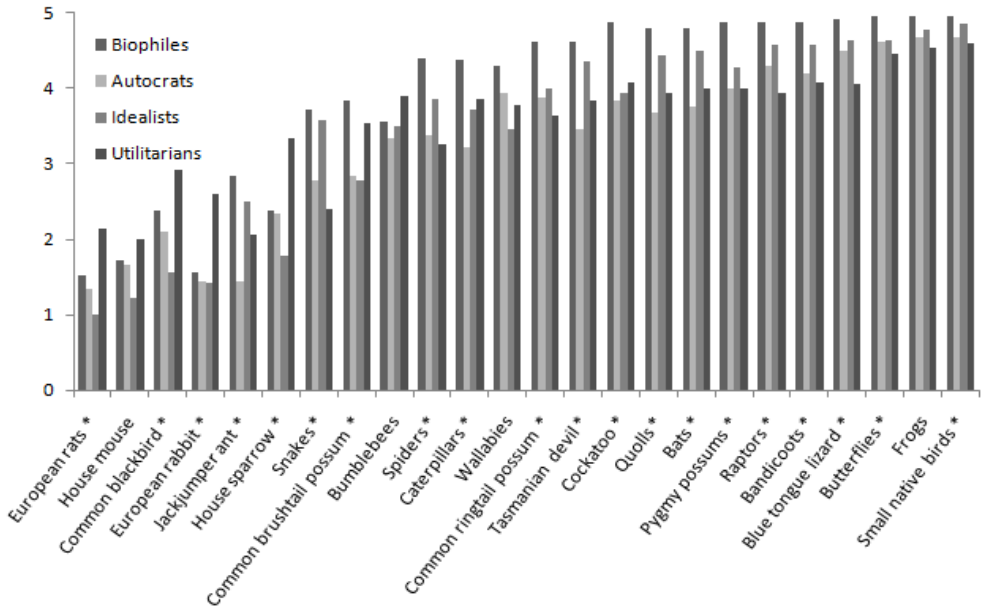

Figure 14: Mean 'happiness to share property with' scores for fauna species. 1 = very unhappy; 2 = unhappy; 3 = neutral; 4 = happy; 5= very happy. Species with asterisks have a significant level of variation in a four-way group comparison.

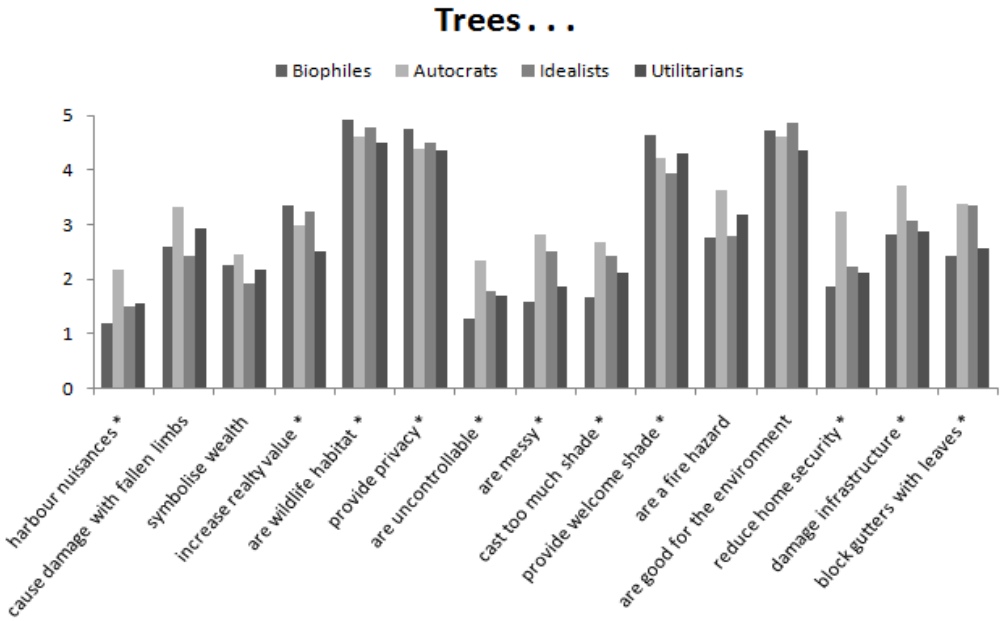

Figure 15: Variation in group opinion regarding statements relating to trees within 25 m of homes. 1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree. Statement endings with asterisks have mean levels of agreement that vary significantly in a four-way comparison between people assemblages (Appendix Q).

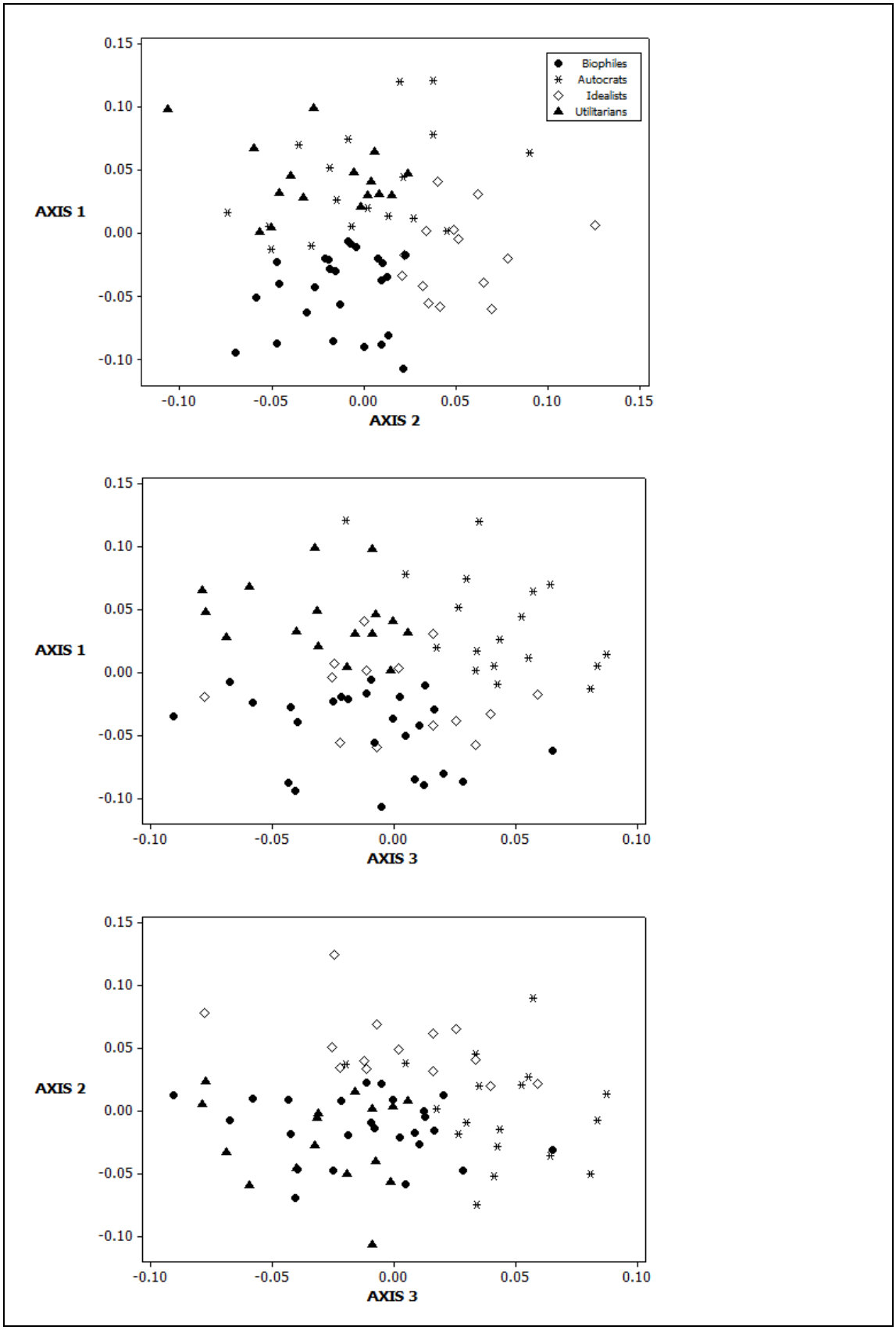

Figure 16: Distribution of exurbanites' survey responses in 3-dimensional ordination space (stress value < 0.20).

Group 2 – Autocratic urbanophiles

Annette: "We have removed a lot of dead trees which were threatening to fall down on us . . ."

Group 2, the autocrats, had a moderate appreciation of exurban nature, but a particularly strong desire to control it. The autocrats were frustrated with aspects beyond their control, particularly things that threatened their safety or sense of order. They were active gardeners and encouraged wildlife to their property with the provision of supplementary food. They nurtured their properties with fertiliser, and battled unwanted visitors with biocides and trapping. They disliked caterpillars more than any other group of people. They valued exurban forests for firewood production, but were concerned with uncontrollable and undesirable aspects of trees, such as the mess and gutter blockages fallen leaves can create, the potential damage to people and property from falling limbs, their flammability, and the nuisance animals they can attract. Autocrats were more inclined than any other group to allow a conservation agency to undertake work on their property if they were compensated for it (presumably because they felt they would have a high level of control over what a conservation agency could do on their property), and were the most likely to relocate into more urbanised environments. Their controlling nature was reflected in pet management, with their dogs restrained more than dogs owned by any other group, and their cats being unrestrained in the daytime the least of any group.

Group 3 – Environmental idealists

April: "I thought I had minimal impact on native wildlife until I filled out this survey"

Group 3, idealists, had a strong appreciation for exurban nature, but not so much for the exurban landscape itself. They valued cheap real estate and environmental conditions, but not to a significant extent more than the other groups of people. They had a low appreciation of romantic, country landscapes and were more inclined than any other group to move to remote bushland. They did not desire space for children or livestock, opportunities for firewood collection, or likeminded neighbours. They were very tolerant of species that can cause harm, particularly snakes and jack jumper ants, and had relatively high levels of appreciation for all native species except brushtail possums and cockatoos. They were very intolerant of exotic species, but did not necessarily list them as problematic, indicating a high level of idealism in regards to biological invasions. They were strongly opposed to feeding wildlife and were generally against any human interference with native or exotic wildlife, very seldom making an exception to this when hunting European rabbits on their property. The environmental idealists included few cat owners, but the level of pet control for those that did own pets did not seem to reflect the preservation ethos of the group. Their cats were uniformly unrestrained at day and night, and their dogs captured and harassed wildlife more frequently than the dogs owned by any other group. They did, however, agree more strongly than any other group that both dogs and cats are a serious threat to wildlife in the urban fringe.

Group 4 – Rural utilitarians

Arthur: [Points to a nearby patch of forest] "Does it really matter if I clear a bit of the scrub there? I wouldn't mind some more space for the horses."

Group 4, utilitarians, valued exurban properties for their capacity to provide a source of income, and for the amenity of space, which could be used by children or livestock and for active recreation. They lamented the difficulty in clearing more land for livestock, and were more inclined than other group to relocate to a more rural landscape, as well as being the least likely group to move to the city. Many utilitarians owned pets, particularly dogs, and were not inclined to restrain their dogs during the day. They had a relatively low appreciation of native wildlife, but were more tolerant than the autocrats, and had a significantly stronger appreciation of exotic species than the other three groups. They did not consider trees to be particularly desirable, nor did they see them as problematic.

Variation in the properties of different people

The four groups of exurbanites were distributed randomly across the exurban landscape with respect to: substrate; land cover composition within a surrounding 1 km radius; and proximity to wildland remnants (Table 28). At a property scale, group was related to some aspects of land cover. Paradoxically, the autocrats, a group defined by their fear of trees, had the highest proportion of properties with > 50 % cover of exurban forest. This relationship was particularly pronounced in South Arm.

Table 28: Variation in the composition of properties owned by each of the people assemblages. Values for continuous variables are means and values for class variables are group percentages.

	Biophiles (n = 25)	Autocrats (n = 18)	Idealists (n = 14)	Utilitarians (n = 16)	P
Both regions					
Habitat richness	5.480 a	4.722 a	5.357 a	5.625 a	0.257
Property size (ha)	2.2515 a	2.0997 a	2.0852 a	2.0250 a	0.338
Mudstone	56.00 a	44.44 a	35.71 a	43.75 a	0.650
Undefined soils	20.00 a	38.89 a	28.57 a	37.50 a	0.512
Igneous	30.00 a	16.67 a	35.71 a	18.75 a	0.606
> 25 % exurban forest cover	60.00 a	72.22 a	64.29 a	68.75 a	0.854
> 50 % exurban forest cover	28.00 ab	61.11 a	42.86 ab	12.50 b	0.021
> 25 % forest cover	76.00 a	83.33 a	64.29 a	68.75 a	0.393
> 50 % forest cover	40.00 a	77.78 b	50.00 ab	50.00 ab	0.100
Dune grassland	4.00 a	5.56 a	7.14 a	0.00 a	N/A
Grassy woodland	48.00 a	33.33 a	21.43 a	18.75 a	0.181
Modified forest	20.00 a	33.33 a	28.57 a	43.75 a	0.435
Pasture paddock	60.00 a	27.78 a	50.00 a	43.75 a	0.214
Rank grass / tussocky paddock	32.00 a	5.56 a	7.14 a	31.25 a	0.067
Saltmarsh	20.00 a	0.00 a	0.00 a	0.00 a	N/A
Chicken yard	32.00 a	16.67 a	7.14 a	31.25 a	0.279
Lawn	56.00 a	50.00 a	42.86 a	68.75 a	0.523
Mixed minimal input garden	20.00 a	16.67 a	7.14 a	56.25 b	0.008
Native garden	48.00 a	50.00 a	21.43 a	18.75 a	0.096
Orchard	28.00 a	27.78 a	42.86 a	31.25 a	0.778
Productive garden	50.00 a	33.33 a	71.43 a	31.25 a	0.095
Showy flower garden	20.00 ab	16.67 ab	50.00 a	12.50 b	0.065
Water: dam and / or river	64.00 a	50.00 a	57.14 a	81.25 a	0.283
Windbreak	48.00 a	38.89 a	42.86 a	50.00 a	0.908
Woodland garden	12.00 a	11.11 a	21.43 a	6.25 a	0.649
Housing density within 250 m	6.120 a	6.556 a	5.000 a	6.563 a	0.419
% forest in surrounds (1km)	63.80 a	63.69 a	59.94 a	58.55 a	0.893
Proximal to 100 ha remnant	48.00 a	72.22 a	50.00 a	0.75 a	0.194
Proximal to remnant (no road)	48.00 a	66.67 a	28.57 a	68.75 a	0.088
Equine	12.00 a	27.78 ab	14.29 ab	43.75 b	0.095
Non-equine stock	12.00 ab	0.00 a	35.71 b	25.00 b	0.036
Stock	20.00 a	27.78 ab	42.86 ab	62.50 b	0.037
Intra-regional					
Kingborough					
Habitat richness	4.900 a	5.625 a	6.000 a	6.429 a	0.361
Property size (ha)	2.2444 a	2.0386 a	2.0546 a	2.0003 a	0.714
Mudstone	30.00 a	25.00 a	25.00 a	14.29 a	0.905
Undefined soils	10.00 a	37.50 a	12.50 a	42.86 a	0.285
Igneous	60.00 a	37.50 a	62.50 a	42.86 a	0.679
> 25 % exurban forest cover	70.00 a	62.50 a	50.00 a	71.43 a	0.800
> 50 % exurban forest cover	30.00 a	37.50 a	25.00 a	28.57 a	0.958
> 25 % forest cover	80.00 a	75.00 a	57.50 a	71.43 a	0.242

	Biophiles (n = 25)	Autocrats (n = 18)	Idealists (n = 14)	Utilitarians (n = 16)	P
> 50 % forest cover	40.00 a	62.50 a	25.00 a	28.57 a	0.419
Dune grassland	0.00 a	0.00 a	0.00 a	0.00 a	N/A
Grassy woodland	40.00 a	37.50 a	0.00 a	0.00 a	0.060
Modified forest	10.00 a	37.50 a	37.50 a	42.86 a	0.413
Pasture paddock	60.00 a	37.50 a	75.00 a	57.14 a	0.505
Rank grass / tussocky paddock	30.00 a	12.50 a	12.50 a	28.57 a	0.702
Saltmarsh	0.00 a	0.00 a	0.00 a	0.00 a	N/A
Chicken yard	10.00 a	25.00 a	12.50 a	28.57 a	0.710
Lawn	60.00 a	62.50 a	62.50 a	100.00 a	0.275
Mixed minimal input garden	30.00 a	25.00 a	12.50 a	42.86 a	0.616
Native garden	20.00 a	50.00 a	37.50 a	42.86 a	0.587
Orchard	10.00 a	37.50 a	50.00 a	57.14 a	0.175
Productive garden	33.33 a	37.50 a	62.50 a	42.86 a	0.644
Showy flower garden	10.00 a	37.50 a	25.00 a	14.29 a	0.514
Water: dam and / or river	70.00 a	62.50 a	75.00 a	71.43 a	0.958
Windbreak	30.00 a	50.00 a	62.50 a	57.14 a	0.529
Woodland garden	20.00 a	12.50 a	37.50 a	14.29 a	0.606
Housing density within 250 m	4.700 a	5.625 a	4.750 a	6.429 a	0.116
% forest in surrounds (1km)	68.13 a	59.30 a	59.60 a	52.49 a	0.546
Proximal to 100 ha remnant	80.00 a	87.50 a	62.50 a	100.00 a	0.289
Proximal to remnant (no road)	80.00 a	87.50 a	37.50 a	85.71 a	0.080
Equine	10.00 a	50.00 a	25.00 a	42.86 a	0.256
Non-equine stock	10.00 ab	0.00 a	50.00 b	14.29 ab	0.052
Stock	10.00 a	50.00 ab	62.50 b	57.14 ab	0.092
South Arm					
Habitat richness	6.467 a	4.000 b	4.500 ab	5.000 ab	0.004
Property size (ha)	2.2563 a	2.1485 a	2.1259 a	2.0442 a	0.587
Mudstone	73.33 a	60.00 a	50.00 a	66.67 a	0.760
Undefined soils	26.67 a	40.00 a	50.00 a	33.33 a	0.760
Igneous	0.00 a	0.00 a	0.00 a	0.00 a	N/A
> 25 % exurban forest cover	53.33 a	80.00 a	83.33 a	66.67 a	0.428
> 50 % exurban forest cover	26.67 ac	80.00 b	66.67 ab	0.00 c	0.001
> 25 % forest cover	73.33 a	90.00 a	83.33 a	66.67 a	0.622
> 50 % forest cover	40.00 a	90.00 b	83.33 ab	66.67 ab	0.051
Dune grassland	6.67 a	10.00 a	16.67 a	0.00 a	N/A
Grassy woodland	53.33 a	30.00 a	50.00 a	33.33 a	0.613
Modified forest	26.67 a	30.00 a	16.67 a	44.44 a	0.687
Pasture paddock	60.00 a	20.00 a	16.67 a	33.33 a	0.126
Rank grass / tussocky paddock	33.33 a	0.00 a	0.00 a	33.33 a	0.083
Saltmarsh	26.67 a	0.00 a	0.00 a	0.00 a	N/A
Chicken yard	46.67 a	10.00 a	0.00 a	33.33 a	0.081
Lawn	53.33 a	40.00 a	16.67 a	44.44 a	0.494
Mixed minimal input garden	13.33 a	10.00 a	0.00 a	66.67 b	0.004
Native garden	66.70 a	50.00 ab	0.00 b	0.00 b	0.002
Orchard	40.00 a	20.00 a	33.33 a	11.11 a	0.428
Productive garden	60.00 ab	30.00 ab	83.33 a	22.22 b	0.056
Showy flower garden	26.67 a	0.00 a	83.33 b	11.11 a	0.002

	Biophiles (n = 25)	Autocrats (n = 18)	Idealists (n = 14)	Utilitarians (n = 16)	P
Water: dam and / or river	60.00 a	40.00 a	33.33 a	88.89 a	0.096
Windbreak	60.00 a	30.00 a	16.67 a	44.44 a	0.244
Woodland garden	6.67 a	10.00 a	0.00 a	0.00 a	N/A
Housing density within 250 m	7.067 a	7.300 a	5.333 a	6.667 a	0.732
% forest in surrounds (1km)	60.91 a	67.20 a	60.38 a	63.27 a	0.946
Proximal to 100 ha remnant	26.67 a	60.00 a	33.33 a	55.56 a	0.305
Proximal to remnant (no road)	26.67 a	50.00 a	16.67 a	55.56 a	0.286
Equine	13.33 a	10.00 a	0.00 a	44.44 a	0.095
Non-equine stock	13.33 a	0.00 a	16.67 a	33.33 a	N/A
Stock	26.67 ab	10.00 a	16.67 ab	66.66 b	0.041

Garden types varied strongly with exurbanite group, but not consistently in a pattern logically predicted by group ideology (Table 28). The proportion of group members with native gardens did not vary significantly over both regions, but was highest amongst autocrats and was the most frequently recorded garden on their properties. However, in South Arm only, native gardens were significantly more frequent on the properties of biophiles than any other group. Productive gardens were significantly associated with idealists in South Arm, and were the most common garden type on the properties of biophiles and idealists overall. A large proportion of idealists also had showy flower gardens. Utilitarians were strongly associated with the mixed minimal input garden type, which occurred on their properties more than any other garden type and proportionately more than in any other exurbanite group. Group ideologies were also expressed through livestock ownership, with livestock ownership significantly higher among utilitarians than biophiles.

Socioeconomic and demographic variation in groups

A high proportion of biophile and idealist households had at least one tertiary educated resident (Table 29). Biophile households were significantly more educated

than autocrats and utilitarians. Compared to other groups, biophiles in particular, a high proportion of utilitarian households had at least one resident aged < 25 years.

Table 29: Proportion of groups with socioeconomic and demographic characteristics

	Biophiles	Autocrats	Idealists	Utilitarians	P
Both regions					
Tertiary educated	80.00 a	44.44 b	78.57 ab	50.00 b	0.038
Home owned	96.00 a	100.00 a	100.00 a	100.00 a	N/A
Household weekly income > $1300	54.17 a	56.25 a	66.67 a	71.43 a	0.702
Resident(s) aged < 25 years	44.00 a	38.89 a	50.00 ab	81.25 b	0.061
Resident(s) aged 25 – 54 years	72.00 a	72.22 a	85.71 a	93.75 a	0.288
Resident(s) aged > 55 years	40.00 a	38.89 a	21.43 a	18.75 a	0.368
Intra-regional					
Kingborough					
Tertiary educated	80.00 a	50.00 a	87.50 a	57.14 a	0.296
Home owned	100.00 a	100.00 a	100.00 a	100.00 a	N/A
Household weekly income > $1300	44.44 a	33.33 a	62.50 a	83.33 a	0.299
Resident(s) aged < 25 years	30.00 a	25.00 a	62.50 ab	85.71 b	0.054
Resident(s) aged 25 – 54 years	70.00 a	75.00 a	75.00 a	100.00 a	0.478
Resident(s) aged > 55 years	30.00 a	50.00 a	25.00 a	28.57 a	0.712
South Arm					
Tertiary educated	80.00 a	40.00 a	66.67 a	44.44 a	0.159
Home owned	93.33 a	100.00 a	100.00 a	100.00 a	N/A
Household weekly income > $1300	60.00 a	70.00 a	75.00 a	62.50 a	0.925
Resident(s) aged < 25 years	53.33 a	50.00 a	33.33 a	77.78 a	0.370
Resident(s) aged 25 – 54 years	73.33 a	70.00 a	100.00 a	88.89 a	0.394
Resident(s) aged > 55 years	46.67 a	30.00 a	16.67 a	11.11 a	0.259

Wildlife on group properties

There were a small number of relationships between groups and landowner-reported species distributions (Appendix R). Overall, *P. peregrinus* was reported on significantly more properties of idealists than properties of biophiles and utilitarians. A large proportion of idealists also reported European rats on their properties. Biophiles reported disproportionately few *O. anatinus*, but, in contrast reported *P. gunnii* significantly more than utilitarians, particularly within Kingborough. Within

South Arm only, idealists reported a significantly greater distribution of *T. aculeatus* than any other class.

Significant relationships between wildlife frequencies and distributions observed by spotlight survey were: a high proportion of utilitarian properties on which dogs were observed; a low proportion of autocrat properties on which cats were observed; the paucity of *P. gunnii* observations on the properties of idealists; and the significantly higher number of biophile properties on which *O. cuniculus* was recorded, compared to those of utilitarians; all of which were only evident within the South Arm region (Appendix R).

The effects of people and pets independent of group

The effects of landowner activities and domestic livestock

The presence of livestock on a property was significantly related to the distribution and frequency of a small number of mammals in Kingborough (Table 30). Stock variables, however, were negatively related to measures of extensive tree cover at the property scale ($P < 0.05$). Thus, the relationships between stock and mammalian fauna mirror the habitat relationships discussed in the previous chapter. At the property level, pesticide application was not significantly related to any single species, but was significantly negatively related to two collective groups, macropods (frequency) and peramelids (distribution). Livestock and human activity were of almost no influence on South Arm mammalian fauna, with the exception of fertiliser application, which was negatively related to total native species richness recorded by spotlight.

Table 30: Significant relationships between mammal species and exurban livestock and exurbanite land management practices. P/A = species recorded at a site during at least one spotlight survey (distribution); F = frequency of occurrence within spotlight surveys; LO = species reported by landowner (distribution).

	Equine stock	Fertiliser application	Habitat gardening	Non-equine stock	Provision of food to wildlife	Stock
Kingborough						
Native species richness						+ ve
T. billardierii [LO]	- ve					
I. obesulus [P/A]	+ ve					+ ve
O. cuniculus [F]	+ ve				- ve	
O. cuniculus [P/A]			- ve			
P. gunnii [P/A]				+ ve		+ ve
P. tridactylus [P/A]						+ ve
European *Rattus* spp. [LO]						+ ve
South Arm						
Native species richness		- ve				

Reported prey of domestic mesopredators

There were 49 dog owners among the 73 survey respondents; twenty-two in Kingborough (66.67 % of respondents) and 27 in South Arm (67.50 %). Only 28 respondents were cat owners; eleven in Kingborough (33.33 %) and 17 in South Arm (42.50 %). A large variety of life forms were reported as prey of domestic predators, including bats, flying insects, a duck, *A. swainsonii*, *D. viverrinus* and *T. aculeatus* (Appendix S).

Cats were reported as having preyed upon *O. cuniculus*, European rats, *M. musculus*, small-bodied birds, peramelids, and *P. breviceps* significantly more than dogs (Table 31). Dogs were not reported as having preyed upon any life form

significantly more than cats, but there appeared to be a weak tendency for them to capture more possums. Herpetofauna and macropods were reported as the prey of cats and dogs in almost equal proportions, while potoroids were not recorded as the prey of either species. A significantly greater proportion of Kingborough cat owners reported European rats as cat prey than cat owners in South Arm.

Table 31: Percentage of pet owners that reported species and life forms as prey of their pets. Shared lowercase letters within rows indicate no significant difference. Shared uppercase letters within rows indicate no significant difference in 'total' values.

	Cats in Kingborough	Dogs in Kingborough	Cats in South Arm	Dogs in South Arm	Cats total	Dogs total
European *Rattus* spp.	54.55 a	0.00 b	11.76 b	3.70 b	28.57 A	2.04 B
Herpetofauna	9.09 a	4.55 a	17.65 a	3.70 a	14.29 A	12.24 A
Large-bodied birds (≥ 50 g)	18.18 a	18.18 a	23.53 a	3.70 a	21.43 A	10.20 A
Macropods	9.09 a	4.55 a	0.00 a	0.00 a	3.57 A	2.04 A
Mus musculus	54. 55 a	0.00 b	35.29 a	3.70 b	42.86 A	2.04 B
O. cuniculus	54.55 ab	27.27 a	70.59 b	29.63 a	64.29 A	28.57 B
P. breviceps	9.09 a	0.00 a	11.76 a	0.00 a	10.71 A	0.00 B
Peramelids	27.27 a	0.00 b	29.41 a	7.41 ab	28.57 A	4.08 B
Potoroids	0.00 a	0.00 a	0.00 a	0.00 a	0.00 A	0.00 A
Ringtail and brushtail possums	9.09 a	4.55 a	0.00 a	18.52 a	3.57 A	12.24 A
Small-bodied birds (< 50 g)	54.55 a	4.55 b	35.29 a	0.00 b	42.86 A	2.04 B

Relationships between domestic predators and mammal observations and reports

Variables relating to cat presence and activity were significantly negatively related to tree cover at the property scale in each region, but particularly strongly in South Arm (Appendix M, Appendix N). As a consequence, all of the significant relationships between cats and wild mammals are consistent with habitat associations (Table 32). All of the wild mammals positively associated with cats are species positively associated with paddocks, and, in contrast, tree-dependent possums were negatively related to a single cat variable.

Within South Arm, dogs were positively related to the presence of stock, and, thus, indirectly positively associated with land clearance in the same way (but less significantly) than pet cats. This relationship is ostensibly responsible for the positive relationship between dog variables and the frequencies of occurrence of the two peramelid species (Table 32). However, some dog variables were also negatively related to *P. gunnii* variables, as well as negatively related to another paddock dweller *O. cuniculus*, and negatively related to *P. tridactylus*, a species not significantly associated with any habitat types in South Arm (Chapter 4). These relationships indicate a negative effect of exurban dog presence and activity independent of wild mammal habitat associations and the non-uniform distribution of pets.

The negative impact of pet dogs was even more strongly evident within Kingborough sites. Dogs in Kingborough were negatively related to macropods, potoroids, peramelids, and possums, some of the individual species within those groups, and *D. viverrinus*. Although all dog variables are strongly correlated, diurnally

active and unrestrained dogs were evidently particularly detrimental. The contrasting habitat preferences of all the mammals negatively affected by Kingborough dogs make it unlikely that unmeasured habitat influences are actually responsible for the mammal relationships to dog properties. In Kingborough, water was the only habitat or location variable strongly significantly related to dog variables. The relationship was positive, and water itself was positively related to habitat heterogeneity. There was also a weak negative relationship between dog presence and property locations within 250 m of a 100 ha wildland remnant, but remnant proximity was not limiting in Kingborough and had no significant relationship with any mammal species in that region (Chapter 4).

Table 32: Significant relationships between mammal reports and observations and aspects of domestic mesopredator distribution and behaviour within exurbia. P/A = species recorded at a site during at least one spotlight survey (distribution); F = frequency of occurrence within spotlight surveys; LO = species reported by landowner (distribution).

	Cat(s) resident	Cat catches wildlife	Cat harasses wildlife	Cat unrestrained day	Cat observed during spotlighting	Dog(s) resident	Dog(s) observed during spotlight survey	Dog(s) unrestrained day	Dog harasses wildlife	Dog catches wildlife	Abundance of resident dogs
Kingborough											
Total species richness	+ ve								- ve	- ve	
Native species richness			+ ve								
B. gaimardi P/A						- ve	- ve	- ve			
D. viverrinus LO						- ve					
I. obesulus P/A	+ ve	+ ve		+ ve							
P. gunnii F								- ve			
Peramelids F								- ve			
Possums F		- ve						- ve			
Macropods F								- ve			
M. rufogriseus P/A					+ ve						
Potoroids P/A							- ve	- ve	- ve		
Potoroids LO						- ve					
P. tridactylus P/A									- ve	- ve	

	Cat(s) resident	Cat catches wildlife	Cat harasses wildlife	Cat unrestrained day	Cat observed during spotlighting	Dog(s) resident	Dog(s) observed during spotlight survey	Dog(s) unrestrained day	Dog harasses wildlife	Dog catches wildlife	Abundance of resident dogs
South Arm											
I. obesulus [F]										+ ve	
O. cuniculus [F]					+ ve						- ve
P. gunnii [F]						- ve		+ ve			- ve
P. gunnii [P/A]			+ ve								
P. gunnii [LO]						- ve					
Peramelids [F]		+ ve						+ ve			
Potoroids [P/A]									- ve		
P. tridactylus [P/A]						- ve					

Discussion

This chapter has found that exurban Hobart is occupied by four groups of people with distinct sets of nature conservation ideals and behaviours, uniform levels of wealth, and varied levels of tertiary education and household youthfulness; that these groups of people are distributed uniformly across the exurban landscape, but are associated with certain land cover types at the property scale; that the exurban distribution and frequency of native mammals are largely unrelated to landowner groups; that, independent of group, landowner behaviour is affecting exurban mammals through practices such as pesticide application and domestic mesopredator ownership and control; that the effects of exurban populations of domestic cats are confounded by the habitat associations of their owners; that a number of wild mammal species are averse to properties with active and unrestrained dogs; that species averse to dog presence and activity are not necessarily predated by dogs, indicating harmful levels of non-lethal harassment.

The two most nature loving groups of exurban people, biophiles and idealists, were the most educated. The relationship between biophilia and different types of tertiary education has not been quantified, but it is probably strongest in those that have studied the natural sciences, as knowledge of wildlife is positively related to intrinsic, rather than aesthetic, love of animals, and negatively related to fear of wildlife and to a utilitarian view of the land (Miller, 2003). Biophiles and idealists collectively constituted the majority of this sample of exurbanites, which is consistent with the finding that exurbanites are nature loving and place a high value on proximity to nature (Kaplan and Austin, 2004), and that rural / urban views to nature conservation do not vary monotonically along an anthropocentric-biocentric continuum (Racevskis and Lupi, 2006).

Both nature loving groups had high proportions of productive gardens, which is the rarest garden type in suburban Hobart (Kirkpatrick *et al.*, 2007) but is positively associated with large block size elsewhere (Smith *et al.*, 2005). Biophiles in South Arm expressed their desire to attract nature through the creation of native gardens, which are utilised by high numbers of birds and butterflies (Daniels and Kirkpatrick, 2006b; Burghardt *et al.*, 2009). However, the nature loving ideals of biophiles and idealists were not reflected in the extent of forest cover on their properties, or their location in the landscape, suggesting that natural vegetation is of secondary importance to housing design when buying a property, or that people appraise exurban virtues at a broader scale than those measured in this study, such as simply comparing the natural amenities of exurbia to those of suburbia (Rasker and Hansen, 2002).

Although the properties of the nature loving groups did not support significantly higher numbers of mammalian wildlife than other classes, their residents did report significantly higher numbers of certain species. Nature lovers evidently pay a disproportionately high amount of attention to the wildlife on their property, which could influence the accuracy of species distributions based on landowner accounts (Harrison, 1998; Toms and Newson, 2006), but does not always do so (Lunney *et al.*, 2009).

Rodents, both native and exotic, are typically considered undesirable urban fauna (Bjerke *et al.*, 2003; Tisdell *et al.*, 2005). The high proportion of idealists (the class that disliked introduced species the most) that reported European rats on their property may indicate that rats are benefiting from the idealists' reluctance to interfere with wildlife, or that there is a correlation between level of exposure and species likeability. Consistent with suburban studies, exurbanites overall considered small native birds, butterflies and bandicoots to be highly desirable residents (Bjerke *et al.*, 2003; Davies *et al.*, 2004; FitzGibbon and Jones, 2006). Quolls and bats, however, were seen as more desirable by exurban residents than residents in previous studies (Davies *et al.*, 2004; Tisdell *et al.*, 2005), which may indicate spatial variation in attitudes. Such variation is evident in the attitudes of French residents towards *Sturnus vulgaris* (Clergeau *et al.*, 2001).

If the four groups of the present study do vary spatially in their proportions, then the proportion of autocrats might be expected to peak in urban areas with relatively low levels of tree cover (Jensen *et al.*, 2004; Kirkpatrick *et al.*, 2007). However, the high levels of forest cover on the properties of exurban autocrats is inconsistent with this hypothesis and seemingly conflicts with their negative

attitudes to trees. It may indicate that autocrats initially had a stronger desire to be proximal to nature but this has been overwhelmed by the discord between their controlling nature and the unruly eucalypt forests in which they live. Perhaps the frequency with which they provide supplementary food and their willingness to allow conservation agencies to work on their land are vestiges of a diminished appreciation of nature, maintained in preference to other nature-nurturing actions on grounds on controllability: *ie.* autocrats could selectively attract different species of birds by providing certain types of supplementary food (Parsons *et al.*, 2006), and autocrats could screen conservation projects for suitability. If autocrats relocate to more urbanised and less forested situations, as they are more inclined than any other group to do, they may redevelop a strong appreciation of nature. Conversely, autocrats were more inclined than any other group to agree that trees symbolise wealth, which suggests there may have been an element of prestige in their original desire to live in wealthy forested exurbs.

Many of the autocrats' fears of trees could be lessened by increasing their knowledge of the numerous small trees with non-invasive roots and relatively low levels of flammability, such as *Nothofagus cunninghamii*, *Olearia argophylla* and *Allocasuarina* species. Autocrats are not inclined to read or watch television programs about nature, so increasing their knowledge of trees may need to be done through personal communication, the internet, or local garden centres (Clayton, 2007).

The frequency with which autocrats gardened suggests that the native gardens found on their property are products of their creation, rather than inheritance (Boone *et al.*, 2010). A strong desire for control and structure is typically associated

with manicured gardens (Zagorski *et al.*, 2004; van den Berg and van Winsum-Westra, 2010). Native gardens are often regarded as untidy (Zagorski *et al.*, 2004), but can also be regimented and manicured, particularly when managed by ardent gardeners (Daniels, 2005), and the garden typology used in the present study was based on plant species composition rather than structure. The relationship between autocrats and native gardens may indicate that the autocratic mind desires a certain level of harmony between gardens and the surrounding natural landscape. Autocrats in less forested surrounds may thus be less inclined to establish native gardens. However, very few gardeners in another study stated that they view their garden as a connection to their local landscape (Clayton, 2007) and gardens are more likely to correspond to housing design than the local area (Kirkpatrick *et al.*, 2009). Autocrats may simply establish native gardens because of the difficulty in establishing a diversity of non-native plants under eucalypt canopies, which, in suburban areas, often dominate gardens with a sparse shrub layer (Daniels and Kirkpatrick, 2006a). The autocrats' frequent applications of fertilisers may be an attempt to counter the disproportionate consumption of nutrients by eucalypts. Similarly, mature native trees harbour greater numbers of invertebrates than recently planted native and exotic plants (Bhullar and Majer, 2000). Thus, forest invertebrates may be periodically invading the gardens of autocrats, prompting them to apply pesticides.

The disproportionately frequent use of chemicals by autocrats did not have any evident effects on the mammalian fauna on their properties because, like most activities, it was not restricted to one group of people. Overall, impacts of pesticide application were evident in the negative relationship between peramelids and Kingborough properties on which pesticides are used. This potentially indicates that

chemicals applied to subterranean biota could be harming insectivorous species in higher trophic levels, which has previously been postulated (Lenghaus *et al.*, 1990). The negative relationship between macropods and properties on which pesticides are used has not been reported elsewhere.

The views expressed by the utilitarians in this study may be fostered by a family history in agriculture, because landowners that are reliant on their properties as a source of income have a low appreciation of the aesthetic or intrinsic value of wildlife on their land (Daley *et al.*, 2004). Utilitarians prefer the aesthetic of managed landscapes compared to naturalistic landscapes (van den Berg and Koole, 2006). One exurban utilitarian lamented the decline of agriculture in South Arm, and was particularly concerned at the loss of the bucolic aesthetic:

Jack - "The first thing people do when they buy a block of [cleared] land is plant a bunch of trees . . . it will become like bush again."

If exurban utilitarianism is a result of farming genealogy, the ideal has most likely declined in proportion to other exurban sociologies throughout the rural population turnaround (Hugo, 1994; Walmsley *et al.*, 1998; Curry *et al.*, 2001). However, the high value utilitarians placed on space for children to play, and their youthfulness, could indicate that the current exurban utilitarian ideal is a temporary consequence of family formation and may become less evident as families age. The association between the youthful exurban utilitarians and minimal input gardens contrasts with the situation in suburban Hobart, where minimal input gardens are associated with suburbs with high proportions of retirees (Kirkpatrick *et al.*, 2007). Similarly, the most educated exurban classes had no significant association with woodland

gardens, which are particularly common in suburbs with high levels of tertiary education (Kirkpatrick *et al.*, 2007). Associations between socioeconomic groups and garden types may thus vary between areas with varied property size.

Utilitarians had high levels of livestock ownership, however, the effects of livestock ownership within, or independent of, exurbanite groups, could not be disentangled from the pastoral associations of livestock owners and certain wild species. Within other exurban areas in the USA, livestock grazing has a negative effect on native rodents and rabbits independent of housing development (Bock *et al.*, 2006a; Bock *et al.*, 2006c), but can decrease the richness of exotic plant species (Maestas *et al.*, 2003) and increase local abundances of grasshoppers (Bock *et al.*, 2006b). Exurban populations of birds and butterflies have been found to be largely unaffected by grazing (Bock *et al.*, 2007; Bock *et al.*, 2008), but there is some evidence that domestic herbivores may preferentially graze the food plants of small nectivorous birds (Chapter 3).

The most evident consequence of human opinion and behaviour was domestic mesopredator ownership and control. The popular opinion expressed by residents in the present study and one other (Woolcott Research, 2002), that urban cats are a greater threat to wildlife than urban dogs, is seemingly based on the relative levels of predation being observed by pet owners. Cats are widely acknowledged as a prolific predator of avifauna (Baker *et al.*, 2008; van Heezik *et al.*, 2010), but equally as many exurban cats preyed upon small mammals, as has been found elsewhere (Barratt, 1997b; Woods *et al.*, 2003; Baker *et al.*, 2005). Conversations with exurban landowners indicated rabbits, in particular, were the most frequently taken prey,

which is consistent a study of cat predation in an agricultural area (Coman and Brunner, 1972).

The disproportionately high number of cats, compared to dogs, preying upon exurban peramelids is consistent with observations of a population of *P. gunnii* in Hamilton, Victoria, in which *F. catus* predation was the cause of 17.8 % of all confirmed cases of mortality, compared to only 2.2 % from *C. f. familiaris* predation (Dufty, 1994b). However, in the present study, *P. gunnii* and domestic *F. catus* were both distributed non-uniformly across the exurban landscape, and shared a positive association with cleared land, seemingly because landowners with forested properties are making a decision not to own cats due to their threat to wildlife.

If predation from domestic cats was an additive demographic pressure on rabbits and *P. gunnii* within exurbia, then cat presence would be expected to nullify the two species' associations with cleared land, which would have resulted in no significant relationships between cats and the two species. The fact that the two wild species were positively associated with cat properties suggests that cat presence is not affecting their populations within cleared habitats, and may indicate that bandicoot and rabbit mortality as a result of cat predation is largely compensatory within exurbia (*ie.* captured individuals are primarily surplus to viable population requirements and would most likely suffer mortality through other causes if not for cat predation). Similarly, cats appear to have little effects on small mammal populations in suburban reserves (Barratt, 1998; Kays and DeWan, 2004). However, in other urban situations, bandicoot mortality as a result of introduced predators is considered to a be a significant threat to population viability (Scott *et al.*, 1999; Banks, 2004).

The negative relationship between bandicoot frequency and reported distribution and domestic dogs, suggests that bandicoots are modifying their activity patterns to spatially and temporally avoid harassment from dogs. Other mammal species in exurbia (Vogel, 1989; Harrison, 1997), and urban reserves (George and Crooks, 2006), avoid human-associated disturbance temporally through disproportionately high levels of nocturnal activity. In the current study, increased nocturnal activity among *P. gunnii* was evident in the contrast between reported and observed distributions of that species on the properties of utilitarians. Many utilitarians might be unaware than *P. gunnii* inhabits their property because their unrestrained pet dogs have synchronised their activity levels with that of their owners, creating a disparity between bandicoot and human activity patterns.

Increased nocturnal activity was not evident in macropods and possums, but these groups exhibited broader temporal avoidance by utilising properties with dogs less frequently than properties without dogs. This is consistent with the hypothesis that domestic mesopredators are primarily responsible for the housing density aversion exhibited by *T. billardierii* and *T. vulpecula* (Chapter 4). Human activity can be a significant disturbance factor in itself, but dog activity compounds human disturbance (Lenth *et al.*, 2008).

Because of their small size and predominantly terrestrial behaviour, predation regulates potoroid populations (Hill and Triggs, 1985; Seebeck and Rose, 1989) and influences dense habitat selection by some members of the family (Heinsohn, 1968; Christensen, 1980). Domestic cats and dogs are predators of potoroids (Schlager, 1981; Hill and Triggs, 1985; Delroy *et al.*, 1986), but exurban pet-owners in the present study did not report potoroids as prey. Thus, the spatial avoidance of dog

properties by potoroids may be a response to non-lethal predation and harassment. Similar non-lethal effects of domestic mesopredator activity have been found to reduce songbird fecundity, potentially causing their urban populations to decline in the UK (Beckerman *et al.*, 2007).

D. viverrinus exhibited spatial avoidance of dog properties in Kingborough and were preyed upon by a domestic dog in South Arm, as they are elsewhere (Jones *et al.*, 2003). Dietary distinction (Parmalee, 1953; Eberhard, 1954; Blackhall, 1980; Catling, 1988; Paltridge *et al.*, 1997) and the fact that adult *D. viverrinus* display anti-predator behaviour in response to auditory cues of *F. catus* (Jones *et al.*, 2004) evidently enables eastern quolls to persist in the presence of cats, but not dogs.

Conclusion

All of the mammal groups that have particularly large home ranges sizes and were disproportionately disadvantaged within exurban South Arm, displayed spatial or temporal avoidance of domestic dogs. Thus the presence of domestic dogs is evidently compounding or entirely responsible for housing-associated disturbance of flightless mammal species. Therefore, clustering houses at suburban densities within isolated landscapes may not be the only way to maintain mammal diversity.

Wildlife and nature evidently play an important role in exurban residents' quality of life, and residents displayed a high willingness to adopt nature conservation measures. However, because wildlife were largely unaffected by landowner characteristics and attitudes, programs aimed at increasing biophilia amongst urban residents may be largely ineffective at improving urban nature conservation.

Future directions for exurban planning and research

The present study has found that avifauna and flightless mammals vary in their response to exurbanisation of sclerophyll forests. Bird communities varied spatially in accordance with local habitats and the presence of noisy miners, but were not affected by the proximity or density of houses. Wildland bird species assemblages, which included many urban-sensitive species, persisted where the native tree canopy remained. Thus, the only effect of exurbia on wildland avifaunal assemblages is the patchy loss of habitat, rather than the spatial isolation of habitat patches (Andren, 1994). There is likely to be a critical proportion of natural habitat retention that is necessary to maintain the original avifauna in both suburban and exurban landscapes, as there is in other landscapes, where it appears to be approximately 30 % (Andren, 1994). Nonetheless, the anthropogenic habitats that replaced natural forests supported distinct avifaunal assemblages. Gardens supported typical synanthropes and paddocks supported a species poor but spatially heterogeneous community. This bird community heterogeneity resulted in a native exurban avifauna that was richer than the avifauna of control areas of native vegetation and the adjacent suburbs Hobart surveyed by Daniels and Kirkpatrick (2006). Thus, a large area of native forest would support greater densities of urban-sensitive species, but lower species and community diversity, than an equivalent area of

exurbia. Thus, planning and land use regulations that ensure both heterogeneity of habitat and the retention of most of the area of native plant communities are likely to result in urban areas that contribute substantially to avifaunal conservation.

Further research on avifaunal responses to Antipodean exurbanisation should aim to determine: if exurban forest birds have larger home ranges sizes than their wildland counterparts, which they may need in order to compensate for the patchy loss of forest; the effects of exurbia on species that were infrequently recorded by the point count method, particularly raptors and native pigeons; the comparative level of breeding success of ground-nesting species within exurbia compared to non-urban landscapes with similar landscape habitat heterogeneity; the differences between grassland bird communities in exurbia and in non-urban landscapes. Species or group specific avifaunal studies are warranted to determine: if the weak associations between certain foliage gleaners and forests with modified understoreys are a consequence of prey availability; the efficacy of perching posts in reducing range size and increasing paddock utilisation among Petroicines; the extent to which interspecific harassment limits the extent of hunting territory available to raptors on forest edges; if the paucity of parasitic cuckoos in exurbia is a consequence of low numbers of breeding attempts by their host species.

In contrast to avifauna, flightless mammals were affected by the spatial configuration of exurban parcels and adjacent wildland remnants. The division of forests into exurban properties can evidently alter the extent of habitat available to a variety of mammal species, resulting in disproportionately adverse effects on species with large home range requirements in areas where access to wildlands is

limited. There are alternatives to forest development, such as urban consolidation, pastoral development, and a lowering of population growth. However, if increasing land values continue to entice private landowners to subdivide areas of forest, adequate planning to ensure biodiversity conservation is vital. In areas where remnant access is limited or initial forest patch size is small, it may be best to densely cluster housing. This suffers the risk that a dichotomy will be created between human and non-human animals, potentially leading to what is termed an extinction of experience (Miller, 2005), which may lead to higher levels of apathy towards nature-conservation among residents. However, it appears that the survival of wild animals in and around exurban estates is independent of the attitudes of residents, and clustered housing will preserve a greater area of natural habitat (Gonzalez-Abraham *et al.*, 2007), which will enable the persistence of a greater diversity of mammals (Deacon and Mac Nally, 1998; Cox *et al.*, 2003). However, because the presence of domestic dogs was a major housing-associated disturbance factor, experimental restrictions on dog ownership and activity may reveal that flightless mammals can persist within exurban developments independent of adjacent wildland remnants, which, contingent upon a critical proportion of natural habitat remaining in the landscape, will enable residents to be integrated with nature at a desirable density for those that value the amenity of space. Nature lovers may not necessarily view legislation against exurban dog ownership or activity as an impingement on their liberty. Within another Australian city, residents were found to have a high willingness to control the activities of domestic cats, but were markedly less inclined to support cat-free suburbs (Lilith *et al.*, 2006). If dogs are not

restricted or restrained, then, even if forest housing is clustered, they may be a disturbance factor not only within urban estates, but also up to 200 m into adjacent wildland remnants (Goldingay and Whelan, 1997; Lenth *et al.*, 2008). Thus, urban-adjacent wildland habitats may need disturbance buffer zones around a core protected area, the size of which may vary depending on the local fauna.

In addition to experimental restrictions on dog ownership, further research on the effects of exurbanisation on mammalian fauna should include: a comparative study of mammalian assemblages within exurbia and within non-urban landscapes with similar habitat mosaics, with particular emphasis on whether high fecundity is advantageous in certain situations; a comparison of exurban demographic pressures acting upon mammals, particularly domestic mesopredator predation and mortality through road trauma; the effects of exurbanisation on species under-sampled by the spotlight survey method; a test of the efficacy of nest box provision in increasing the abundance of hollow-dependent species within exurbia; and the potential impacts of red foxes *Vulpes vulpes* in exurbia.

Research into the responses of other lifeforms to exurbanisation could include: the value of exurban dams in frog conservation; the effects of domestic cat predation on exurban herpetofauna; the extent to which exurbanisation alters local geochemistry and the extent of mycorrhizal development.

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Appendix A: Descriptions of all independent variables tested against quantitative bird variables

Abbreviation	Variable	Description	Geographical level	Source
> 10 % EverTreeCover	> 10 % evergreen tree cover	> 10 % cover of evergreen woody plants > 8 m in height.	Site	Field sampling
Ferns and graminoids	> 10 % fern and graminoids cover	> 10 % cover of tussock graminoids (excluding grass species), and / or hard-leaved ferns of the genera *Pteridium* and *Blechnum*.	Site	Field sampling
	> 10 % forb cover	> 10 % cover of herbaceous flowering plants that are not graminoids.	Site	Field sampling
> 10 % ModForSrnds	> 10 % modified forest surrounds	> 10 % of the land surrounding the site, to a distance of 100 m, is modified forest, in accordance with the description Chapter 2.	Local	Field sampling
> 10 % sm. shrub	> 10 % small shrub cover	> 10 % cover of woody vegetation less than 2 m in height.	Site	Field sampling
> 10 % SurrTreeCover	> 10 % surrounding tree cover	> 10 % of the land surrounding the site, to a distance of 100 m, is covered by woody vegetation > 8 m in height.	Local	Field sampling
> 25 % Forest surrounds	> 25 % forest surrounds	> 25 % of the land surrounding the site, to a distance of 100 m, is covered by exurban or wildland forest.	Local	Field sampling
> 25 % EverTreeCover	> 25 % evergreen tree cover	> 25 % cover of evergreen woody plants > 8 m in height.	Site	Field sampling
	> 25 % grass cover	> 25 % cover of tussock and / or spreading grass species.	Site	Field sampling
Paddock surrounds	> 25 % paddock surrounds	> 25 % of the land surrounding the site, to a radius of 100 m, is paddock habitat, in accordance with the description in Chapter 2.	Local	Field sampling
	Bare ground	Soil uncovered by living or decaying plant matter, and / or impervious surfacing.	Site	Field sampling
Bird bath	Bird bath	A shallow vessel containing water during at least 5 bird surveys.	Site	Field sampling
Forest patch > 100 ha	Forest patch > 100 ha	Exurban forest and modified forest sites that were embedded within a patch of continuous native tree cover > 100 ha in area.	Local	Aerial photos
	Chicken yard	An enclosure housing chickens *Gallus domesticus*.	Site	Field sampling

Abbreviation	Variable	Description	Geographical level	Source
	Coastal surrounds	Land surrounding the site, to a distance of 100 m, contains coastal habitat in accordance with the description in Chapter 2.	Local	Field sampling
	Deciduous tree(s)	At least one deciduous woody plant > 8 m in height.	Site	Field sampling
	Dolerite	Site located on dolerite substrate.	Site	Field sampling
Dom. strata > 8 m	Dominant strata > 8 m	Tallest vegetation strata with > 20 % cover has a mean height of > 8 m.	Site	Field sampling
	Equine stock	At least one horse *Equs caballus* and / or donkey *Equs asinus* has access to site.	Site	Field sampling
	Fencing	A wooden, wire, or stone fence > 2 m in length.	Site	Field sampling
	Impervious surfacing	Soil covered by impervious metal and / or concrete.	Site	Field sampling
	Large shrub(s)	At least one woody plant 2-4 m in height.	Site	Field sampling
Max Veg Height > 8 m	Maximum vegetation height > 8 m	Tallest plant within site is greater than 8 m in height.	Site	Field sampling
	Mudstone	Site located on mudstone substrate	Site	Field sampling
	Non-equine stock	At least one domestic bovine, ovine, caprine, and / or camelid has access to site.	Site	Field sampling
	Paddock patch > 100 ha	Paddock sites embedded within a continuous patch of paddock habitat > 100 ha in area.	Local	Aerial photos
	Plant species richness	Total number of vascular plants recorded within the site.	Site	Field sampling
	Remnant proximity	Site is located within 250 m of a wildland remnant > 100 ha in area and devoid of any level of housing.	Local	Aerial photos
	Sandy soil	Site located on a substrate of undefined soils originating from Tertiary sediments, alluvial deposits, or recently deposited shell beds.	Site	Field sampling
	Small tree(s)	At least one woody plant 4-8 m in height.	Site	Field sampling
	Stock	Combines ‘equine stock’ and ‘non-equine stock’.	Site	Field sampling
Supp. Feeding	Supplementary feeding	Grain or human food scraps supplied on at least one bird survey.	Site	Field sampling
	Surrounding dam(s)	Land surrounding the site, to a distance of 100 m, contains at least one dam, in accordance with the description in Chapter 2.	Local	Field sampling
	Surrounding garden(s)	Land surrounding the site, to a distance of 100 m, contains garden habitat, in	Local	Field sampling

Abbreviation	Variable	Description	Geographical level	Source
		accordance with the description in Chapter 2.		
Surr. Imperv. Surf.	Surrounding impervious surfacing	Land surrounding the site, to a distance of 100 m, contains impervious surfacing.	Local	Field sampling
	Surrounding saltmarsh	Land surrounding the site, to a distance of 100 m, contains Chenopod or Aizoan saltmarsh(es).	Local	Field sampling

Appendix B: Significant relationships between independent variables relating to attributes of bird survey sites in the Kingborough region.

+/- indicates positive or negative relationship; 1: *P* = < 0.05; 2: *P* = < 0.01; 3: *P* = < 0.001

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	26	27	28	29	33
1. > 10 % evergreen tree cover																											
2. > 10 % fern and graminoids cover	+2																										
3. > 10 % forb cover	−3																										
4. > 10 % small shrub cover																											
5. > 25 % evergreen tree cover	+3	+2	−1																								
6. > 25 % grass cover	−3	−3		−2	−3																						
7. Bare ground																											
8. Bird bath	−1		+2			+1																					
9. Chicken yard																											
10. Deciduous tree(s)	−2	−1	+3			+2		+3																			
11. Dolerite																											
12. Dominant strata > 8 m	+3	+2	−3		+3	−3				−2																	
13. Equine stock																											
14. Fencing		−1																									
15. Impervious surfacing	−1	−1						+3	+1	+3		−1															
16. Large shrub(s)	+2			+1	+1	−3						+2	−3														
17. Maximum vegetation height > 8 m	+3			+1	+3	−3						+3				+2											
18. Mudstone		−1									−3																
19. Non-equine stock																−1											
20. Plant species richness (mean)			+3	+2			+2	+3		+3			−1		+3	+2	+1										
21. Sandy soil											−3							−1									
22. Small tree(s)	+2				+2	−3						+1				+3	+2		−1								

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	26	27	28	29	33
23. Stock				−1	−1								+3			−3			+3	−1		−1					
24. Supplementary feeding			+1					+1												+3							
25. > 10 % modified forest surrounds					−1																						
26. > 10 % surrounding tree cover	+1	+1			+1	−2					+1	+2															
27. > 25 % forest surrounds	+1	+2		+2		−3						+2				+2	+2						+3				
28. > 25 % paddock surrounds	−1	−3				+3						−2		+1		−2							−3	−3			
29. Forest patch > 100 ha		+1																					+2	+1	−1		
30. Paddock patch > 100 ha																					−2						
31. Remnant proximity				−2			+1																				
32. Surrounding dam(s)						+1																	−2	−1	+1	−2	
33. Surrounding garden(s)	−1					+1						−1												−2			
34. Surrounding impervious surfacing																								−2			+3

Appendix C: Significant correlations between independent variables relating to attributes of bird survey sites in the South Arm region.

+/- indicates positive or negative relationship; 1: *P* = < 0.05; 2: *P* = < 0.01; 3: *P* = < 0.001

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	23	24	25	27	29	30
1. > 10 % evergreen tree cover																											
2. > 10 % fern and graminoids cover																											
3. > 10 % forb cover	−2	−1																									
4. > 10 % small shrub cover																											
5. > 25 % evergreen tree cover	+1	+1																									
6. > 25 % grass cover	−2	−1		−1																							
7. Bare ground																											
8. Bird bath				+3																							
9. Dominant strata > 8 m	+3		−3		+2	−2		−2																			
10. Equine stock																											
11. Fencing																											
12. Impervious surfacing	−1		+3	+3				+3	−2																		
13. Large shrub(s)				+3		−2		+1				+1															
14. Maximum vegetation height > 8 m	+3	+1				−2			+3				+2														
15. Mudstone		−3					+1																				
16. Non-equine stock				−1							+2		−1														
17. Plant species richness (mean)								+3	−1			+3															
18. Sandy soil		+3					−1								−3												
19. Small tree(s)	+2	+2	−2			−2			+2				+2	+3		−1											
20. Stock				−1		+1				+3			−2			+3			−1								
21. Supplementary feeding	−1		+1	+2				+2				+2					+2										
22. > 10 % modified forest surrounds																											
23. > 10 % surrounding tree cover	+2	+2	−2			−2			+3					+2						−1							
24. > 25 % forest surrounds	+1	+1	−3			−3			+2	−1			+2						+1	−1		+3					

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	23	24	25	27	29	30
25. > 25 % paddock surrounds	−1	−1	+3			+3			−1							−1			−1			−3	−3				
26. Forest patch > 100 ha																−1											
27. Coastal surrounds							−1		−1		−1																
28. Remnant proximity																							+1		−1		
29. Surrounding dam(s)																					+1		−1				
30. Surrounding garden(s)															+1			−1									
31. Surrounding impervious surfacing		−1													+1			−1				−1					+2
32. Surrounding saltmarsh							−1															−1	−1	+1	+3	+1	

Appendix D: Every bird species recorded in exurbia and wildlands, listed in taxonomic order. Light grey columns contain percentage frequency of occurrence. Dark grey columns contain mean abundance per survey. Blank cells equal zero. Species recorded in > 9 surveys were tested for variation in habitat usage with Pearson's chi-squared. Bold values indicate the preferred habitat (highest frequency of occurrence) of those species that displayed significant variation. N.A. = not applicable (fewer than 9 records).

	Kingborough wildlands	Kingborough exurban forest	Kingborough modified forest	Kingborough gardens	Kingborough paddocks	P value	South Arm wildlands	South Arm exurban forest	South Arm modified forest	South Arm gardens	South Arm paddocks	P value	Kingborough wildlands	Kingborough exurban forest	Kingborough modified forest	Kingborough gardens	Kingborough paddocks	South Arm wildlands	South Arm exurban forest	South Arm modified forest	South Arm gardens	South Arm paddocks
Brown goshawk		0.75				N.A.						N.A.		0.01								
Collared sparrowhawk		0.75				N.A.						N.A.		0.01								
Grey goshawk			0.71			N.A.						N.A.			0.01							
Australian wood duck					1.79	N.A.					1.50	N.A.					0.04					0.04
Tawny frogmouth		0.75				N.A.			2.86			N.A.		0.01						0.03		
Masked lapwing			1.43		**8.93**	0.000				0.89	**6.77**	0.000			0.01		0.15				0.04	0.20
Laughing kookaburra	1.43	1.50	0.71			N.A.	1.43					N.A.	0.01	0.02	0.01			0.01				
Fan-tailed cuckoo		0.75	0.71			N.A.						N.A.		0.01	0.01							
Horsfield's bronze-cuckoo		1.50				N.A.				0.89		N.A.		0.01							0.01	
Shining bronze-cuckoo		3.01		1.68		N.A.	4.29	0.79	1.43	0.89		N.A.		0.04		0.03		0.04	0.01	0.01	0.01	
Brown quail						N.A.					0.75	N.A.										0.02

	Kingborough wildlands	Kingborough exurban forest	Kingborough modified forest	Kingborough gardens	Kingborough paddocks	P value	South Arm wildlands	South Arm exurban forest	South Arm modified forest	South Arm gardens	South Arm paddocks	P value	Kingborough wildlands	Kingborough exurban forest	Kingborough modified forest	Kingborough gardens	Kingborough paddocks	South Arm wildlands	South Arm exurban forest	South Arm modified forest	South Arm gardens	South Arm paddocks
Tasmanian native-hen			2.14			N.A.				4.46	**7.52**	0.000			0.02						0.16	0.22
Brown falcon						N.A.			0.71	0.89		N.A.								0.01	0.01	
Brown thornbill	**25.71**	25.56	18.57	15.97	8.04	0.004	11.43	10.32	11.43	15.18	6.77	0.334	0.63	0.44	0.11	0.27	0.10	0.27	0.26	0.21	0.33	0.10
Scrubtit	1.43					N.A.	1.43					N.A.	0.04					0.01				
Striated fieldwren				0.84		N.A.						N.A.				0.02						
Tasmanian scrubwren	14.29	**15.04**	2.86	1.68	0.89	0.000	1.43					N.A.	0.20	0.24	0.02	0.02	0.01	0.01				
Tasmanian thornbill	**8.57**	8.27	5.71	5.04		0.041	2.86	0.79				N.A.	0.11	0.12	0.04	0.06		0.03	0.01			
Yellow-rumped thornbill			0.71	1.68	3.57	N.A.	1.43	1.59	5.00	2.68	7.52	0.079			0.01	0.07	0.05	0.03	0.02	0.14	0.04	0.35
Australian magpie						N.A.		0.79	5.71	**7.14**	1.50	0.007							0.01	0.12	0.18	0.03
Black currawong	1.43	2.26	0.71	0.84	0.89	N.A.	1.43					N.A.	0.01	0.03	0.01	0.01	0.01	0.01				
Dusky woodswallow						N.A.	1.43	1.59	1.43	1.79	0.75	N.A.						0.01	0.02	0.02	0.04	0.01
Grey butcherbird						N.A.	1.43		3.57		1.50	N.A.						0.01		0.03		0.02
Grey currawong	2.86	2.26	2.86	0.84		0.369	1.43	0.79	0.71	0.89		N.A.	0.03	0.02	0.02	0.01		0.01	0.01	0.01	0.01	
Black-faced cuckoo-shrike		1.50	1.43			N.A.		2.38	1.43			N.A.		0.02	0.01				0.04	0.03		
Forest raven		0.75	2.14	0.84		N.A.		3.97	2.14			N.A.		0.01	0.01	0.01			0.04	0.04		
Beautiful firetail			2.86		0.89	N.A.						N.A.			0.02		0.01					
Common greenfinch						N.A.			0.71	3.57	2.26	N.A.								0.01	0.07	0.03
European goldfinch			6.43	**8.40**	1.79	0.001			3.57	1.79	4.51	N.A.			0.05	0.15	0.04			0.03	0.02	0.09
Tree martin	**8.57**	1.50	1.43	0.84	0.89	0.002		4.76	**11.43**	6.25	3.01	0.005	0.20	0.02	0.01	0.02	0.01		0.06	0.14	0.16	0.07
Welcome swallow		1.50	7.14	**15.13**	8.04	0.000	2.86	3.17	7.14	**13.39**	12.78	0.005		0.04	0.04	0.23	0.13	0.03	0.06	0.09	0.20	0.20
Superb fairy-wren	10.00	16.54	29.29	**57.14**	21.43	0.000	12.86	9.52	14.29	**31.25**	13.53	0.000	0.19	0.25	0.11	1.24	0.36	0.24	0.20	0.34	0.75	0.26

	Kingborough wildlands	Kingborough exurban forest	Kingborough modified forest	Kingborough gardens	Kingborough paddocks	P value	South Arm wildlands	South Arm exurban forest	South Arm modified forest	South Arm gardens	South Arm paddocks	P value	Kingborough wildlands	Kingborough exurban forest	Kingborough modified forest	Kingborough gardens	Kingborough paddocks	South Arm wildlands	South Arm exurban forest	South Arm modified forest	South Arm gardens	South Arm paddocks
Black-headed honeyeater	**11.43**	10.53	**11.43**	5.88	0.89	0.012	**12.86**	12.70	9.29	3.57		0.000	0.33	0.19	0.07	0.08	0.02	0.49	0.21	0.14	0.05	
Crescent honeyeater	**18.57**	12.03	10.71	15.13		0.000	7.14	1.59	5.00	4.46	0.75	0.076	0.33	0.15	0.09	0.24		0.09	0.03	0.06	0.05	0.02
Eastern spinebill	**18.57**	7.52	4.29	12.61	0.89	0.000	7.14	1.59	4.29	2.68	0.75	0.080	0.27	0.08	0.03	0.14	0.01	0.14	0.04	0.09	0.03	0.01
Little wattlebird	1.43	0.75	2.14	3.36		0.273	4.29	0.79	5.71	**30.36**	3.01	0.000	0.01	0.02	0.02	0.05		0.09	0.01	0.09	0.44	0.04
New Holland honeyeater	10.00	17.29	20.71	**47.90**	10.71	0.000	15.71	11.11	13.57	**18.75**	1.50	0.000	0.11	0.30	0.08	0.81	0.13	0.20	0.18	0.26	0.38	0.02
Noisy miner						N.A.		15.87	**21.43**	17.86	5.26	0.000							0.31	0.32	0.30	0.11
Strong-billed honeyeater	5.71	**8.27**	5.00	4.20		0.049	1.43					N.A.	0.23	0.24	0.05	0.09		0.03				
Yellow-throated honeyeater	12.86	15.04	**19.29**	11.76	3.57	0.006	17.14	**34.13**	13.57	8.93	3.01	0.000	0.14	0.17	0.10	0.13	0.04	0.26	0.40	0.19	0.13	0.03
Yellow wattlebird		3.76	**5.00**	1.68		0.046	2.86	0.79	0.71			N.A.		0.04	0.04	0.02		0.04	0.01	0.01		
Satin flycatcher	**5.71**	3.01	1.43			0.018	7.14		0.71			N.A.	0.11	0.06	0.01			0.13		0.01		
Golden whistler	4.29	4.51	7.14	2.52		0.052	4.29	2.38	5.71		1.50	0.056	0.06	0.05	0.07	0.03		0.04	0.02	0.06		0.01
Grey shrike-thrush	2.86	3.01	5.00	5.04		0.179	1.43	1.59	1.43			N.A.	0.03	0.03	0.05	0.07		0.01	0.02	0.01		
Olive whistler		2.26	0.71	0.84	0.89	N.A.			0.71			N.A.		0.02	0.01	0.01	0.01			0.01		
Forty-spotted pardalote						N.A.			0.71			N.A.								0.01		
Spotted pardalote	1.43	7.52	**9.29**	4.20	0.89	0.013	5.71	**15.87**	14.29	7.14	0.75	0.000	0.01	0.10	0.07	0.04	0.02	0.07	0.21	0.26	0.12	0.01
Striated pardalote	**10.00**	9.02	7.14	2.52		0.005	**15.71**	11.90	11.43	7.14	0.75	0.001	0.13	0.17	0.06	0.03		0.20	0.21	0.15	0.08	0.01
House sparrow			1.43	**23.53**	8.04	0.000		0.79	2.14	**29.46**	5.26	0.000			0.01	0.87	0.14		0.02	0.04	1.27	0.08
Dusky robin	7.14	5.26	7.86	9.24	3.57	0.506	7.14	3.17	2.86	0.89	2.26	0.181	0.10	0.11	0.05	0.11	0.05	0.09	0.03	0.04	0.01	0.02
Flame robin	2.86	2.26	1.43	0.84	1.79	0.851	4.29		2.14	0.89		N.A.	0.04	0.04	0.01	0.02	0.04	0.04		0.04	0.02	
Pink robin	1.43	0.75		0.84		N.A.						N.A.	0.01	0.01		0.01						
Scarlet robin	7.14	1.50	**15.00**	14.29	8.04	0.001	12.86	9.52	15.00	5.36	8.27	0.109	0.09	0.02	0.09	0.22	0.11	0.19	0.13	0.18	0.10	0.14

	Kingborough wildlands	Kingborough exurban forest	Kingborough modified forest	Kingborough gardens	Kingborough paddocks	P value	South Arm wildlands	South Arm exurban forest	South Arm modified forest	South Arm gardens	South Arm paddocks	P value	Kingborough wildlands	Kingborough exurban forest	Kingborough modified forest	Kingborough gardens	Kingborough paddocks	South Arm wildlands	South Arm exurban forest	South Arm modified forest	South Arm gardens	South Arm paddocks
Grey fantail	11.43	20.30	**21.43**	13.45	3.57	0.000	12.86	11.11	8.57	3.57	4.51	0.053	0.13	0.23	0.11	0.17	0.05	0.16	0.13	0.11	0.05	0.05
Common starling		2.26	2.14	5.04	2.68	0.306			1.43	**8.04**	3.76	0.001		0.06	0.01	0.14	0.04			0.03	0.12	0.08
Silvereye	5.71	9.77	11.43	**15.97**	1.79	0.004	7.14	3.97	3.57	5.36	0.75	0.177	0.16	0.14	0.06	0.30	0.02	0.07	0.10	0.04	0.10	0.01
Bassian thrush		0.75		0.84		N.A.						N.A.		0.02		0.01						
Common blackbird		5.26	12.14	**25.21**	6.25	0.000			1.43	**16.96**	0.75	0.000		0.05	0.06	0.27	0.08			0.01	0.21	0.01
Galah			0.71		0.89	N.A.			0.71			N.A.			0.01		0.02			0.01		
Blue-winged parrot						N.A.	1.43					N.A.						0.01				
Eastern rosella						N.A.		2.38	**5.71**	5.36		0.015							0.03	0.09	0.11	
Green rosella	4.29	5.26	7.14	9.24	0.89	0.072	10.00	3.17	8.57	**11.61**		0.001	0.09	0.08	0.06	0.15	0.04	0.17	0.06	0.12	0.19	
Musk lorikeet						N.A.		1.59	2.14			N.A.							0.03	0.06		
Swift parrot						N.A.	1.43					N.A.						0.01				

Appendix E: Taxonomy, origin, and biological and ecological traits of all species recorded in exurbia and wildlands
*** TN = Tasmanian native species; AN = Australian native species, introduced to Tasmania; E = Exotic species**
**** Male and female weights listed for dimorphic species**
***** 1 = Higgins (1999); 2 = Higgins and Peter (2002); 3 = Higgins *et al.* (2006); 4 = Higgins *et al*. (2001); 5 = Marchant and Higgins (1990); 6 = Marchant and Higgins (1993)**

ORDER **Family** Common name	Linnaean name	Origin*	Primary feeding guild	Nest type	Migratory status	Body size (g) **	Reference***
ACCIPITRIFORMES							
Accipitridae							
Brown goshawk	*Accipiter fasciatus*	TN	Carnivore	Bowl/ platform	Resident	M: 310 F: 570	6
Collared sparrowhawk	*Accipiter cirrocephalus*	TN	Carnivore	Bowl/ platform	Resident	M: 125 F: 240	6
Grey goshawk	*Accipiter novaehollandiae*	TN	Carnivore	Bowl/ platform	Resident	M: 350 F: 680	6
ANSERIFORMES							
Anseranatidae							
Australian wood duck	*Chenonetta jubata*	TN	Herbivore	Cavity	Resident	800	5
CAPRIMULGIFORMES							
Podargidae							
Tawny frogmouth	*Podargus strigoides*	TN	Insectivore	Open cup/ platform	Resident	M: 350 F: 280	1
CHARADRIIFORMES							
Charadriidae							

ORDER **Family** Common name	Linnaean name	Origin*	Primary feeding guild	Nest type	Migratory status	Body size (g) **	Reference***
Masked lapwing	*Vanellus miles*	TN	Insectivore	Ground	Resident	230-400	6
CORACIIFORMES **Alcedinidae**							
Laughing kookaburra	*Dacelo novaeguineae*	AN	Carnivore	Cavity	Resident	310-380	1
CUCULIFORMES **Cuculidae**							
Fan-tailed cuckoo	*Cacomantis flabelliformis*	TN	Insectivore	Parasitic	Summer visitor	50	1
Horsfield's bronze-cuckoo	*Chalcites basalis*	TN	Insectivore	Parasitic	Summer visitor	23	1
Shining bronze-cuckoo	*Chalcites lucidus*	TN	Insectivore	Parasitic	Summer visitor	25	1
GALLIFORMES **Phasianidae**							
Brown quail	*Coturnix ypsilophora*	TN	Granivore/ insectivore	Ground	Resident	90-120	6
GRUIFORMES **Rallidae**							
Tasmanian native-hen	*Tribonyx mortierii*	TN	Granivore/ herbivore	Ground/ riparian	Resident	1300	6
FALCONIFORMES **Falconidae**							
Brown falcon	*Falco berigora*	TN	Carnivore	Bowl/ platform	Resident	M: 470 F: 625	6

ORDER **Family** Common name	Linnaean name	Origin*	Primary feeding guild	Nest type	Migratory status	Body size (g) **	Reference***
PASSERIFORMES							
Acanthizidae							
Brown thornbill	*Acanthiza pusilla*	TN	Insectivore	Dome	Resident	7	2
Scrubtit	*Acanthornis magna*	TN	Insectivore	Dome	Resident	10	2
Striated fieldwren	*Calamanthus fuliginosus*	TN	Insectivore	Dome	Resident	20	2
Tasmanian scrubwren	*Sericornis humilis*	TN	Insectivore	Dome	Resident	18	2
Tasmanian thornbill	*Acanthiza ewingii*	TN	Insectivore	Dome	Resident	7	2
Yellow-rumped thornbill	*Acanthiza chrysorrhoa*	TN	Insectivore	Dome	Resident	9	2
Artamidae							
Australian magpie	*Cracticus tibicen*	TN	Omnivore	Open cup/ bowl	Resident	220-350	3
Black currawong	*Streptera fuliginosa*	TN	Omnivore	Open cup/ bowl	Resident	M: 405 F: 340	3
Dusky woodswallow	*Artamus cyanopterus*	TN	Insectivore	Open cup	Summer visitor	35	3
Grey butcherbird	*Cracticus torquatus*	TN	Carnivore	Open cup/ bowl	Resident	90	3
Grey currawong	*Streptera versicolor*	TN	Omnivore	Open cup/ platform	Resident	350	3
Campephagidae							
Black-faced cuckoo-shrike	*Coracina novaehollandiae*	TN	Insectivore	Open cup/ platform	Summer visitor	115	3
Corvidae							
Forest raven	*Corvus tasmanicus*	TN	Omnivore	Open cup/ bowl	Resident	650	3
Estrildidae							

ORDER **Family** Common name	Linnaean name	Origin*	Primary feeding guild	Nest type	Migratory status	Body size (g) **	Reference***
Beautiful firetail	*Stagonopleura bella*	TN	Granivore	Dome	Resident	14	3
Fringillidae							
Common greenfinch	*Chloris chloris*	E	Granivore	Open cup	Resident	28	3
European goldfinch	*Carduelis carduelis*	E	Granivore	Open cup	Resident	14	3
Hirundinidae							
Tree martin	*Petrochelidon nigricans*	TN	Insectivore	Cavity	Summer visitor	15	3
Welcome swallow	*Hirundo neoxena*	TN	Insectivore	Open cup	Summer visitor	15	3
Maluridae							
Superb fairy-wren	*Malurus cyaneus*	TN	Insectivore	Dome	Resident	9-12	4
Meliphagidae							
Black-headed honeyeater	*Melithreptus affinis*	TN	Insectivore	Open cup	Resident	15	4
Crescent honeyeater	*Phylidonyris pyrrhopterus*	TN	Nectivore	Open cup	Resident	M: 18 F: 14	4
Eastern spinebill	*Acanthorhynchus tenuirostris*	TN	Nectivore	Open cup	Resident	11	4
Little wattlebird	*Anthochaera chrysoptera*	TN	Nectivore	Open cup	Resident	M: 75 F: 60	4
New Holland honeyeater	*Phylidonyris novaehollandiae*	TN	Nectivore	Open cup	Resident	20	4
Noisy miner	*Manorina melanocephala*	TN	Insectivore	Open cup	Resident	70-80	4
Strong-billed honeyeater	*Melithreptus validirostris*	TN	Insectivore	Open cup	Resident	25	4
Yellow-throated honeyeater	*Lichenostomus flavicollis*	TN	Insectivore	Open cup	Resident	M: 33 F: 28	4
Yellow wattlebird	*Anthochaera paradoxa*	TN	Nectivore	Open cup	Resident	M: 200 F: 150	4

ORDER **Family** Common name	Linnaean name	Origin*	Primary feeding guild	Nest type	Migratory status	Body size (g) **	Reference***
Monarchidae							
Satin flycatcher	*Myiagra cyanoleuca*	TN	Insectivore	Open cup	Summer visitor	17	3
Pachycephalidae							
Golden whistler	*Pachycephala pectoralis*	TN	Insectivore	Open cup	Resident	25	2
Grey shrike-thrush	*Colluricincla harmonica*	TN	Carnivore	Open cup	Resident	76	2
Olive whistler	*Pachycephala olivacea*	TN	Insectivore	Open cup	Resident	40	2
Pardalotidae							
Forty-spotted pardalote	*Pardalotus quadragintus*	TN	Insectivore	Cavity	Resident	11	2
Spotted pardalote	*Pardalotus punctatus*	TN	Insectivore	Chamber	Resident	9	2
Striated pardalote	*Pardalotus striatus*	TN	Insectivore	Cavity/ chamber	Summer visitor	12	2
Passeridae							
House sparrow	*Passer domesticus*	E	Granivore	Dome/cavity	Resident	29	3
Petroicidae							
Dusky robin	*Melanodryas vittate*	TN	Insectivore	Open cup	Resident	27	2
Flame robin	*Petroica phoenicea*	TN	Insectivore	Open cup	Resident	13	2
Pink robin	*Petroica rodinogaster*	TN	Insectivore	Open cup	Resident	10	2
Scarlet robin	*Petroica boodang*	TN	Insectivore	Open cup	Resident	13	2
Rhipiduridae							
Grey fantail	*Rhipidura albiscapa*	TN	Insectivore	Open cup	Summer visitor	8	3

ORDER **Family** Common name	Linnaean name	Origin*	Primary feeding guild	Nest type	Migratory status	Body size (g) **	Reference***
Sturnidae							
Common starling	*Sturnus vulgaris*	E	Omnivore	Cavity	Resident	80	3
Timaliidae							
Silvereye	*Zosterops lateralis*	TN	Omnivore	Open cup	Summer visitor	11	3
Turidae							
Bassian thrush	*Zoothera lunulate*	TN	Insectivore	Open cup	Resident	100	3
Common blackbird	*Turdus merula*	E	Omnivore	Open cup	Resident	90	3
PSITTACIFORMES **Cacatuidae**							
Galah	*Eolophus roseicapillus*	AN	Granivore	Cavity	Resident	330	1
Psittacidae							
Blue-winged parrot	*Neophema chrysostoma*	TN	Granivore	Cavity	Summer visitor	50-60	1
Eastern rosella	*Platycercus eximius*	TN	Granivore	Cavity	Resident	100-110	1
Green rosella	*Platycercus caledonicus*	TN	Granivore	Cavity	Resident	M: 150 F: 120	1
Musk lorikeet	*Glossopsitta concinna*	TN	Nectarivore	Cavity	Resident	70	1
Swift parrot	*Lathamus discolour*	TN	Nectarivore	Cavity	Summer visitor	65	1

Appendix F: Active bird nests recorded in exurbia and wildlands between June 2006 and August 2008.
1 = Kingborough; 2 = South Arm; a = exurban forest; b = modified forest; c = garden; d = paddock; e = shelter-belt
*** ANS = Australian native shrub; ANT = Australian native tree; ES = exotic shrub; ET = exotic tree; M = numerous species of mixed origin; TNT = Tasmanian native tree**

	Plant origin and form *	Australian magpie	Black currawong	Blue-winged parrot	Brown goshawk	Common blackbird	Common starling	Dusky robin	Eastern rosella	Forest raven	Galah	Grey fantail	House sparrow	Little wattlebird	Masked lapwing	Noisy miner	Scarlet robin	Spotted pardalote	Striated pardalote	Superb fairy-wren	Tasmanian native-hen	Tasmanian scrubwren	Tawny frogmouth	Welcome swallow	Yellow-rumped thornbill	Yellow wattlebird
Wildlands																										
Eucalyptus amygdalina canopy	TNT																●									
Eucalyptus amygdalina cavity	TNT			●																						
Eucalyptus obliqua canopy	TNT		●																							
Eucalyptus spp. tree stump	TNT																					●				
Eucalyptus tenuiramis cavity	TNT							●																		
Sandstone rock face																			●							
Exurbia																										
Abelia grandiflora hedge	ES											2c														
Acacia melanoxylon canopy	TNT	2e																								
Agonis reflexa nana branches	ANS																			2c						

	Plant origin and form *	Australian magpie	Black currawong	Blue-winged parrot	Brown goshawk	Common blackbird	Common starling	Dusky robin	Eastern rosella	Forest raven	Galah	Grey fantail	House sparrow	Little wattlebird	Masked lapwing	Noisy miner	Scarlet robin	Spotted pardalote	Striated pardalote	Superb fairy-wren	Tasmanian native-hen	Tasmanian scrubwren	Tawny frogmouth	Welcome swallow	Yellow-rumped thornbill	Yellow wattlebird
Allocasuarina verticillata foliage	TNT																								2e	
Dam riparian zone	M																				1c,d 2a,d					
Eucalyptus amygdalina branches	TNT																						2b			
Eucalyptus amygdalina canopy	TNT	2b								2b						2d										
Eucalyptus globulus canopy	TNT										1b															
Eucalyptus globulus cavity	TNT																									
Eucalyptus leucoxylon foliage	ANT																								2d	
Eucalyptus obliqua branches	TNT																									1b
Eucalyptus pulchella cavity	TNT																		2a							
Eucalyptus tenuiramis cavity	TNT			1a															1a							
Grass paddock	M														1d 2d											
Housing cavity							1, 2						1, 2													
Malus sp. branches	ES					1c																				
Melaleuca armillaris foliage	ANT																								2e	
Nesting box							2c		2c				2c													
Pinus radiata canopy	ET				2b																					
Pittosporum tenuifolium branches	ET													2c												
Prunus sp. branches	ET													2c												
Sheds and garages							2					2	2											1, 2		
Soil mound																		1, 2								

Appendix G: Exurban site characteristics significantly related to the occurrence of bird species in Kingborough sites. Degrees of freedom equal one in all cases. * F = Fisher's exact probability test.

	Pearson x^2	*P* value*	Variable influence (+/−)
Black-headed honeyeater			
> 10 % evergreen tree cover	7.543	0.006	+
Dominant strata > 8 m	6.092	0.014	+
Maximum vegetation height > 8 m	11.060	0.001	+
Small tree(s)	6.617	0.010	+
Brown thornbill			
> 25 % grass cover	5.449	0.020	−
Maximum vegetation height > 8 m	4.433	0.035	+
Small tree(s)	5.087	0.024	+
Crescent honeyeater			
> 10 % evergreen tree cover	6.896	0.009	+
> 25 % grass cover	7.951	0.005	−
Dominant strata > 8 m	4.041	0.044	+
Large shrub(s)	6.813	0.009	+
Maximum vegetation height > 8 m	6.967	0.008	+
Small tree(s)	5.862	0.015	+
Common blackbird			
Deciduous tree(s)	4.629	0.031	+
Plant species richness		0.046	+
Dusky robin			
Bird bath	5.708	0.017	+
Supplementary feeding	5.708	0.017	+
Eastern spinebill			
Equine stock	4.490	0.034	−
Impervious surfacing	4.633	0.031	+
Maximum vegetation height > 8 m	4.490	0.034	+
European goldfinch			
> 10 % fern and graminoid cover	12.766	0.000	−

	Pearson x^2	*P* value*	Variable influence (+/−)
> 25 % grass cover	4.170	0.041	+
Surrounding garden(s)	3.328	0.037	+
Golden whistler			
> 10 % evergreen tree cover	6.289	0.012	+
> 10 % forb cover	4.451	0.035	−
> 25 % grass cover	10.143	0.001	−
Fencing	4.303	0.038	+
Green rosella			
> 10 % small shrub cover	5.127	0.024	+
Large shrub(s)	4.884	0.027	+
Small tree(s)	5.133	0.023	+
Stock	6.134	0.013	−
Grey currawong			
> 10 % fern and graminoid cover	4.124	0.042	−
Small tree(s)	4.383	0.036	+
Surrounding garden(s)	10.499	0.001	−
Grey fantail			
> 10 % evergreen tree cover	8.061	0.005	+
> 25 % evergreen tree cover	14.073	0.000	+
Dominant strata > 8 m	6.023	0.014	+
Large shrub(s)	3.957	0.047	+
Maximum vegetation height > 8 m	13.873	0.000	+
Small tree(s)	16.519	0.000	+
Grey shrike-thrush			
Chicken yard		0.041 [F]	+
House sparrow			
> 10 % evergreen tree cover	27.042	0.000	−
> 10 % fern and graminoid cover	9.008	0.003	−
> 10 % forb cover	19.200	0.000	+
> 10 % surrounding tree cover	4.444	0.035	−
> 25 % evergreen tree cover	8.604	0.003	−
> 25 % grass cover	17.810	0.000	+
> 25 % forest surrounds	8.991	0.003	−
> 25 % paddock surrounds	8.991	0.003	+
Dominant strata > 8 m	15.880	0.000	−
Deciduous tree(s)	15.280	0.000	+
Impervious surfacing	4.744	0.029	+

	Pearson x^2	*P* value*	Variable influence (+/−)
Maximum vegetation height > 8 m	5.793	0.016	−
Surrounding garden(s)	4.328	0.037	+
Little wattlebird			
Bare ground	3.877	0.049	+
Masked lapwing			
> 10 % evergreen tree cover	5.400	0.020	−
> 10 % small shrub cover	6.429	0.011	−
> 25 % grass cover	8.514	0.004	+
> 25 % forest surrounds	8.053	0.005	−
> 25 % paddock surrounds	4.354	0.037	+
Equine stock	5.365	0.021	+
Large shrub(s)	8.378	0.004	−
Maximum vegetation height > 8 m	17.734	0.000	−
Plant species richness		0.012	−
Stock	5.409	0.020	+
New Holland honeyeater			
> 10 % forb cover	4.934	0.026	+
Bird bath	4.546	0.033	+
Deciduous tree(s)	8.703	0.003	+
Impervious surfacing	8.061	0.005	+
Large shrub(s)	4.044	0.044	+
Plant species richness		0.000	+
Supplementary feeding	4.546	0.033	+
Surrounding garden(s)	10.626	0.001	+
Surrounding impervious surfacing	7.736	0.005	+
Olive whistler			
> 10 % fern and graminoid cover	6.824	0.009	+
Satin flycatcher			
> 10 % fern and graminoid cover	10.101	0.001	+
> 25 % evergreen tree cover	7.950	0.005	+
> 25 % grass cover	5.680	0.017	−
Sandy soils	7.950	0.005	+
Scarlet robin			
> 10 % fern and graminoid cover	4.194	0.041	−
> 10 % surrounding tree cover	6.000	0.014	−
> 25 % grass cover	4.673	0.031	+
> 25 % forest surrounds	5.896	0.015	−

	Pearson x^2	*P* value*	Variable influence (+/−)
Fencing	4.448	0.035	+
Silvereye			
Bare ground	7.251	0.007	+
Equine stock	5.867	0.015	−
Impervious surfacing	4.308	0.038	+
Large shrub(s)	5.340	0.021	+
Stock	6.004	0.014	−
Surrounding dam(s)	6.080	0.014	−
Spotted pardalote			
> 10 % evergreen tree cover	9.900	0.002	+
Deciduous tree(s)	4.235	0.040	−
Dominant strata > 8 m	6.970	0.008	+
Maximum vegetation height > 8 m	4.080	0.043	+
Small tree(s)	12.629	0.000	+
Striated pardalote			
> 10 % evergreen tree cover	16.615	0.000	+
> 10 % fern and graminoid cover	5.024	0.025	+
> 25 % grass cover	10.922	0.001	−
> 25 % paddock surrounds	8.573	0.003	−
Dominant strata > 8 m	16.357	0.000	+
Maximum vegetation height > 8 m	6.684	0.010	+
Strong-billed honeyeater			
> 10 % evergreen tree cover	8.935	0.003	+
Dominant strata > 8 m	8.890	0.003	+
Large shrub(s)	5.514	0.019	+
Superb fairy wren			
Impervious surfacing	5.414	0.020	+
Mudstone	14.188	0.000	−
Plant species richness		0.025	+
Tasmanian scrubwren			
> 10 % evergreen tree cover	3.996	0.046	+
> 25 % forest surrounds	4.086	0.043	+
Equine stock	4.195	0.041	−
Stock	6.684	0.010	−
Surrounding dam(s)	5.013	0.025	−
Surrounding impervious surfacing	9.318	0.002	−

	Pearson x^2	*P* value*	Variable influence (+/−)
Tasmanian thornbill			
> 10 % evergreen tree cover	3.996	0.046	+
> 25 % evergreen tree cover	4.988	0.026	+
> 25 % grass cover	6.245	0.012	−
> 25 % forest surrounds	4.086	0.043	+
Dominant strata > 8 m	5.867	0.015	+
Large shrub(s)	4.490	0.034	+
Maximum vegetation height > 8 m	4.195	0.041	+
Remnant proximity	4.427	0.035	+
Surrounding dam(s)	9.358	0.002	−
Tree martin			
Surrounding garden(s)		0.042 [F]	−
Welcome swallow			
> 10 % evergreen tree cover	6.301	0.012	−
> 10 % forb cover	5.236	0.022	+
Deciduous tree(s)	6.321	0.012	+
Dominant strata > 8 m	5.473	0.019	−
Yellow-rumped thornbill			
> 10 % evergreen tree cover	4.141	0.042	−
Bird bath		0.036 [F]	+
Fencing	5.680	0.017	+
Stock	7.304	0.007	+
Yellow-throated honeyeater			
> 10 % small shrub cover	5.193	0.023	+
Large shrub(s)	4.044	0.044	+
Maximum vegetation height > 8 m	7.503	0.006	+
Small tree(s)	6.266	0.012	+
Yellow wattlebird			
> 10 % evergreen tree cover	6.968	0.008	+
> 25 % grass cover	4.580	0.032	−
Dominant strata > 8 m	8.780	0.003	+

Appendix H: Exurban site characteristics significantly related to the occurrence of bird species in South Arm sites. Degrees of freedom equal one in all cases. * F = Fisher's exact probability test.

	Pearson x^2	*P* value*	Variable influence (+/−)
Australian magpie			
> 10 % modified forest surrounds	4.196	0.041	+
Fencing	7.834	0.005	+
Plant species richness		0.031	+
Black-headed honeyeater			
> 10 % forb cover	5.731	0.017	−
> 10 % surrounding tree cover	5.135	0.023	+
> 25 % grass cover	7.960	0.005	−
> 25 % forest surrounds	7.225	0.007	+
> 25 % paddock surrounds	5.587	0.018	−
Maximum vegetation height > 8 m	7.253	0.007	+
Small tree(s)	4.974	0.026	+
Surrounding garden(s)	4.628	0.031	−
Brown thornbill			
> 10 % modified forest surrounds	8.407	0.004	−
Supplementary feeding	4.679	0.031	−
Surrounding garden(s)	5.203	0.023	−
Common blackbird			
> 10 % fern and graminoid cover	4.359	0.037	−
> 10 % forb cover	12.559	0.000	+
> 10 % small shrub cover	8.904	0.003	+
> 25 % forest surrounds	5.629	0.018	−
> 25 % paddock surrounds	9.817	0.002	+
Bird bath	14.204	0.000	+
Dominant strata > 8 m	5.911	0.015	−
Impervious surfacing	20.894	0.000	+
Plant species richness		0.000	+
Common greenfinch			
> 10 % forb cover	4.774	0.029	+
> 10 % surrounding tree cover	4.193	0.041	−

	Pearson x^2	*P* value*	Variable influence (+/−)
> 25 % forest surrounds	4.523	0.033	−
> 25 % paddock surrounds	3.892	0.049	+
Plant species richness		0.016	+
Common starling			
> 10 % evergreen tree cover	3.984	0.046	−
> 10 % forb cover	17.357	0.000	+
> 10 % surrounding tree cover	10.102	0.001	−
> 25 % grass cover	6.230	0.013	+
> 25 % forest surrounds	10.673	0.001	−
> 25 % paddock surrounds	10.716	0.001	+
Large shrub(s)	4.908	0.027	−
Maximum vegetation height > 8 m	4.006	0.045	−
Small tree(s)	15.995	0.000	−
Crescent honeyeater			
> 10 % fern and graminoid cover	8.268	0.004	+
> 10 % small shrub cover	7.056	0.008	+
Mudstone	7.407	0.006	−
Sandy soils	7.407	0.006	+
Small tree(s)	4.953	0.026	+
Dusky robin			
> 10 % evergreen tree cover	4.365	0.037	+
> 10 % fern and graminoid cover	4.628	0.031	+
Coastal surrounds	4.998	0.025	−
Dominant strata > 8 m	4.435	0.035	+
Surrounding garden(s)	12.916	0.000	−
Eastern rosella			
Supplementary feeding		0.016 [F]	+
Eastern spinebill			
> 10 % small shrub cover	5.419	0.020	+
> 10 % surrounding tree cover	5.203	0.023	+
> 25 % grass cover	5.203	0.023	−
> 25 % forest surrounds	4.770	0.029	+
Plant species richness		0.044	+
European goldfinch			
> 25 % grass cover	8.950	0.003	+
Non-equine stock		0.003 [F]	+
Forest raven			

	Pearson x^2	*P* value*	Variable influence (+/−)
> 10 % evergreen tree cover	6.719	0.010	+
> 25 % cover evergreen cover		0.048 [F]	+
Dominant strata > 8 m	5.192	0.023	+
Golden whistler			
> 10 % evergreen tree cover	4.365	0.037	+
> 10 % fern and graminoid cover	8.742	0.003	+
> 25 % evergreen tree cover		0.016 [F]	+
Dominant strata > 8 m	4.435	0.035	+
Mudstone	4.908	0.027	−
Sandy soils	4.908	0.027	+
Green rosella			
> 10 % small shrub cover	5.139	0.023	+
Bird bath	6.806	0.009	+
Impervious surfacing	10.664	0.001	+
Maximum vegetation height > 8 m	6.282	0.012	+
Grey butcherbird			
> 25 % grass cover	5.699	0.017	+
> 25 % forest surrounds	6.021	0.014	−
> 25 % paddock surrounds	4.469	0.035	+
Bare ground		0.006 [F]	−
Mudstone	4.143	0.042	−
Sandy soils	4.143	0.042	+
Grey fantail			
> 25 % forest surrounds	5.167	0.023	+
Surrounding garden(s)	4.908	0.027	−
House sparrow			
> 10 % forb cover	4.923	0.027	+
> 25 % forest surrounds	3.893	0.048	−
Dominant strata > 8 m	5.305	0.021	−
Impervious surfacing	9.840	0.002	+
Plant species richness		0.003	+
Little wattlebird			
> 10 % forb cover	5.560	0.018	+
> 25 % forest surrounds	9.834	0.002	−
Impervious surfacing	10.664	0.001	+
Plant species richness		0.010	+
Surrounding dam(s)	6.341	0.012	+

	Pearson x^2	*P* value*	Variable influence (+/−)
Surrounding saltmarsh	5.516	0.019	+
Masked lapwing			
> 10 % forb cover	5.117	0.024	+
> 10 % surrounding tree cover	4.679	0.031	−
> 25 % forest surrounds	4.944	0.026	−
> 25 % paddock surrounds	7.272	0.007	+
Coastal surrounds	6.339	0.012	+
Large shrub(s)	6.339	0.012	−
Small tree(s)	4.990	0.025	−
Surrounding saltmarsh		0.016 [F]	+
Musk lorikeet			
> 10 % evergreen tree cover	5.517	0.019	+
> 10 % fern and graminoid cover	4.050	0.044	+
New Holland honeyeater			
> 10 % fern and graminoid cover	4.718	0.030	+
Noisy miner			
Bird bath	4.926	0.026	+
Bushland patch > 100 ha	10.113	0.001	−
Impervious surfacing	4.926	0.026	+
Scarlet robin			
> 10 % surrounding tree cover	4.624	0.032	+
Maximum vegetation height > 8 m	4.232	0.040	+
Surrounding garden(s)	5.419	0.020	−
Silvereye			
Remnant proximity	4.282	0.039	−
Spotted pardalote			
> 10 % evergreen tree cover	15.038	0.000	+
> 10 % forb cover	4.357	0.037	−
Dominant strata > 8 m	9.187	0.002	+
Maximum vegetation height > 8 m	14.220	0.000	+
Small tree(s)	3.873	0.049	+
Striated pardalote			
> 10 % evergreen tree cover	10.508	0.001	+
> 10 % surrounding tree cover	13.021	0.000	+
> 25 % grass cover	6.951	0.008	−
> 25 % forest surrounds	8.634	0.003	+

	Pearson x^2	*P* value*	Variable influence (+/−)
> 25 % paddock surrounds	7.187	0.007	−
Dominant strata > 8 m	12.988	0.000	+
Maximum vegetation height > 8 m	10.127	0.001	+
Superb fairy-wren			
> 10 % small shrub cover	4.624	0.032	+
Impervious surfacing	4.300	0.038	+
Large shrub(s)	4.715	0.030	+
Plant species richness		0.043	+
Tasmanian native-hen			
> 10 % forb cover	20.140	0.000	+
> 10 % surrounding tree cover	6.750	0.009	−
> 25 % forest surrounds	7.131	0.008	−
> 25 % paddock surrounds	5.927	0.015	+
Dominant strata > 8 m	5.103	0.024	−
Large shrub(s)	6.270	0.012	−
Small tree(s)	4.753	0.029	−
Stock	4.672	0.031	+
Surrounding saltmarsh		0.044 [F]	+
Tree martin			
> 10 % fern and graminoid cover	6.743	0.009	−
> 10 % small shrub cover	5.499	0.019	+
Dominant strata > 8 m	5.160	0.023	−
Fencing	4.204	0.040	+
Large shrub(s)	5.015	0.025	−
Non-equine stock	5.515	0.019	+
Welcome swallow			
> 10 % evergreen tree cover	7.439	0.006	−
> 10 % forb cover	10.029	0.002	+
> 10 % surrounding tree cover	7.795	0.005	−
> 25 % forest surrounds	8.968	0.003	−
> 25 % paddock surrounds	12.508	0.000	+
Bare ground	4.142	0.042	−
Yellow-throated honeyeater			
> 10 % evergreen tree cover	7.254	0.007	+
> 10 % forb cover	4.842	0.028	−
> 10 % surrounding tree cover	7.045	0.008	+
> 25 % grass cover	4.765	0.029	−
> 25 % forest surrounds	11.417	0.001	+

	Pearson x^2	*P* value*	Variable influence (+/−)
> 25 % paddock surrounds	5.690	0.017	−
Coastal surrounds	4.088	0.043	−
Dominant strata > 8 m	8.014	0.005	+
Fencing	3.868	0.049	−
Forest patch > 100 ha	6.306	0.012	+
Impervious surfacing	3.953	0.047	−
Maximum vegetation height > 8 m	11.212	0.001	+
Small tree(s)	4.544	0.033	+
Supplementary feeding	4.428	0.035	−
Surrounding saltmarsh	5.798	0.016	−

Appendix I: Independent variables significantly correlated to bird abundances within Kingborough exurban sites, including the variables that comprise the predictive models.

1 = significantly singly, but does not appear in model; X = model component; * = most explanatory variable within model; +/- = variable exerts a positive/negative influence on bird abundance.

	> 10 % EverTreeCover	Ferns and graminoids	>10% forb cover	> 10 % small shrub cover	> 10 % SurrTreeCover	> 25 % Forest surrounds	> 25 % EverTreeCover	> 25 % grass cover	Paddock Surrounds	Bare ground	Bird bath	Forest patch > 100 ha	Chicken yard	Deciduous tree(s)	Dolerite	Dominant strata > 8 m	Equine stock	Fencing	Impervious surfacing	Large shrub(s)	Max Veg Height > 8 m	Mudstone	Non-equine stock	Paddock patch > 100 ha	Plant species richness	Remnant proximity	Sandy soil	Small tree(s)	Stock	Supplementary feeding	Surrounding dam(s)	Surrounding garden(s)	Surr. Imperv. Surf.
Exotic abundance	1 -	1 -	1+			1 -		1+			1+		X+*	X+*		1 -			1+						1+					1+			
Native abundance										1+	1+		X+							X+*	1+				X+			X+	1 -				
Total abundance			1+							1+	1+		X+*	1+					1+	1+	1+				X+			X+*	1 -	1+			
Exotic species richness	1 -	X -	1+			X -		1+	1+					X+*		1 -		1+	1+													1+	
Native species richness	1+						1+	1 -		1+			X+*			1+				X+	X+							X+	1 -				
Total species richness	1+									1+	1+					1+				X+*	X+							1+	1 -	1+			
Individual species abundances																																	
Black-headed honeyeater	1+						1+									1+					1+												
Brown thornbill	1+						1+									1+			1 -	1+	1+							1+					
Common blackbird			1+								1+		X+*	X+					1+						1+					1+			
Common starling			1+								1+		X+*	X+																1+			

	> 10 % EverTreeCover	Ferns and graminoids	>10% forb cover	> 10 % small shrub cover	> 10 % SurrTreeCover	> 25 % Forest surrounds	> 25 % EverTreeCover	> 25 % grass cover	Paddock Surrounds	Bare ground	Bird bath	Forest patch > 100 ha	Chicken yard	Deciduous tree(s)	Dolerite	Dominant strata > 8 m	Equine stock	Fencing	Impervious surfacing	Large shrub(s)	Max Veg Height > 8 m	Mudstone	Non-equine stock	Paddock patch > 100 ha	Plant species richness	Remnant proximity	Sandy soil	Small tree(s)	Stock	Supplementary feeding	Surrounding dam(s)	Surrounding garden(s)	Surr. Imperv. Surf.
Crescent honeyeater				1+						1+	1+									1+	1+				X+*			X+					
Dusky robin																								1 -							1 -		
Eastern spinebill			1+								1+			1+					1+		1+				1+				1-				
European goldfinch		1 -																															
Flame robin																										1+							
Golden whistler	1+											1 -				1+				1+													
Green rosella													1+						1+										1 -				
Grey currawong																												1+					
Grey fantail							X+				X+*									1+	1+							X+					
Grey shrike-thrush												1 -																					
House sparrow	1 -		X+			1 -		1+	1+		1+		X+*	X+		1 -			1+						1+					1+			
Masked lapwing	1 -			1 -		1 -		1+	1 +							1 -	X+			1 -	X-*				1 -				1+				
New Holland honeyeater														1+					X+*						1+			X+					
Olive whistler		1+											1+																	1+			
Satin flycatcher		1+					X+*	1 -		1-																	X+						
Scarlet robin		1 -				1 -		1+										1+					1+						1+				
Silvereye											X+*		1+					X+		1+					1+								
Spotted pardalote	X+						1+								1+	1+					1+								X+*				
Striated pardalote	1+															1+																	

	> 10 % EverTreeCover	Ferns and graminoids	>10% forb cover	> 10 % small shrub cover	> 10 % SurrTreeCover	> 25 % Forest surrounds	> 25 % EverTreeCover	> 25 % grass cover	Paddock Surrounds	Bare ground	Bird bath	Forest patch > 100 ha	Chicken yard	Deciduous tree(s)	Dolerite	Dominant strata > 8 m	Equine stock	Fencing	Impervious surfacing	Large shrub(s)	Max Veg Height > 8 m	Mudstone	Non-equine stock	Paddock patch > 100 ha	Plant species richness	Remnant proximity	Sandy soil	Small tree(s)	Stock	Supplementary feeding	Surrounding dam(s)	Surrounding garden(s)	Surr. Imperv. Surf.
Strong-billed honeyeater	1+				X+		X+*	1 -								1+				1+													
Superb fairy-wren											1+		1+			X -				X+		X -			X+*				1 -	1+			
Tasmanian scrubwren	1+				1+	1+	X+	1 -	1 -			1+				1+												1+	1 -			1 -	
Tasmanian thornbill	1+				1 +	1+	1+	1 -								1+										X+		X+					X -
Tree martin											1+		1+																	1+			
Welcome swallow	1 -	1 -												1+		1 -																	
Yellow-rumped thornbill	1 -										X+*			1+				X+					1+						X+				
Yellow-throated honeyeater	1+															1+				1+	1+							1+					
Yellow wattlebird	1+							1 -								1+																	

Appendix J: Explanatory power and components of predictive bird abundance models for Kingborough area.

*** *P* = < 0.05, ** *P* = < 0.01, *** *P* = < 0.001**

Response variable	Independent variables	R^2
Exotic bird abundance	Chicken yard ***; Deciduous trees ***	47.43
Native bird abundance	Plant species richness *; Large shrubs *; Small trees *; Chicken yard *	32.78
Total bird abundance	Chicken yard ***; Small trees ***; Plant species richness **	39.50
Exotic species richness	Deciduous trees **; Bracken > 10 % *; > 25 % wildlands surrounds *	29.09
Native species richness	Vegetation height > 8 m**; Chicken yard **; Large shrubs *; Small trees *	43.30
Total species richness	Large shrubs ***; Vegetation height > 8 m**	29.55
Common blackbird	Chicken yard ***, Deciduous tree(s) **	31.26
Common starling	Chicken yard **, Deciduous tree(s) *	22.35
Crescent honeyeater	Plant species richness ***, Small tree(s) **	23.80
Grey fantail	> 25 % evergreen tree cover *, Bird bath **, Small tree(s) *	27.10
House sparrow	> 10 % forb cover *, Chicken yard ***, Deciduous tree **	50.77
Masked lapwing	Equine stock **, Maximum vegetation height > 8 m***	33.58
New Holland honeyeater	Impervious surfacing **, Small tree(s)*	16.19
Satin flycatcher	> 25 % evergreen tree cover *, Sandy soil *	12.66
Silvereye	Bird bath **, Fencing *	20.12
Spotted pardalote	> 10 % evergreen tree cover *, Small tree(s) *	19.20
Strong-billed honeyeater	> 25 % evergreen tree cover **, > 10 % surrounding tree cover *	16.68
Superb fairy-wren	Dominant strata > 8 m **, Large shrub(s) *, Mudstone **, Plant species richness **	36.83
Tasmanian scrubwren	> 25 % evergreen tree cover **, Surrounding impervious surfacing ***	30.55
Tasmanian thornbill	Remnant proximity *, Small tree(s) *, Surrounding dam(s)**, Surrounding impervious surfacing *	28.66
Yellow-rumped thornbill	Bird bath ***, Fencing *, Stock **	31.69

Appendix K: Independent variables significantly correlated to bird abundances within South Arm exurban sites, including the variables that comprise the predictive models.

1 = significantly singly, but does not appear in model; X = model component; * = most explanatory variable within model; +/- = variable exerts a positive/negative influence on bird abundance.

	> 10 % EverTreeCover	Ferns and graminoids	> 10 % forb cover	> 10 % ModBshSrnds	> 10 % sm. shrub	> 10 % SurrTreeCover	> 25 % Forest Srnds	> 25 % EverTreeCover	> 25 % grass cover	Paddock surrounds	Bare ground	Bird bath	Forest patch > 100 ha	Coastal surrounds	Dom. strata > 8 m	Equine stock	Fencing	Impervious surfacing	Large shrub(s)	Max Veg Height > 8 m	Mudstone	Non-equine stock	Plant species richness	Remnant proximity	Sandy soils	Small tree(s)	Stock	Supp. feeding	Surrounding dam(s)	Surrounding garden(s)	Surrounding saltmarsh
Exotic species abundance			X+		1+		1 -			1+								X+*					1+					1+			
Native species abundance					1+													X+*		X+*			1+								
Total abundance			1+		1+					1+								1+					1+								
Exotic species richness	1 -		X+*			1 -	1 -		X+	1+					1 -			1+					1+			1 -					
Native species richness	1+					1+									1+					1+											
Total species richness																				1+			1+								
Individual species abundances																															
Australian magpie										1+							1+						1+					1+			
Black-headed honeyeater				X-*											1+					X+											
Brown thornbill																				1+			1+								
Common blackbird			1+		1+					1+		1+						1+					X+*								X+
Common greenfinch			1+							1+								1+					1+								1+
Common starling			1+			1 -	1 -		1+	1+												1+				1 -					

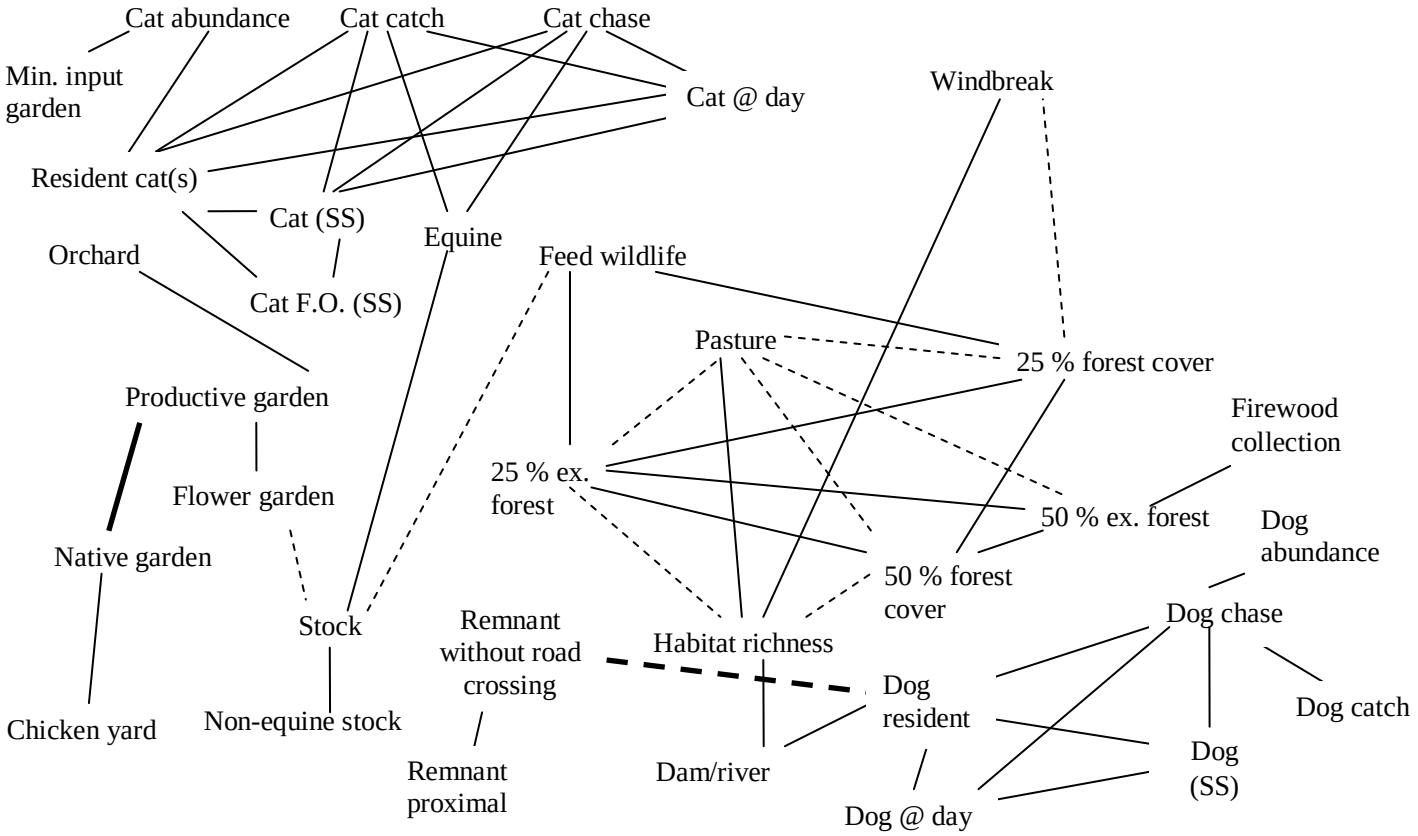
	> 10 % EverTreeCover	Ferns and graminoids	> 10 % forb cover	> 10 % ModBshSrnds	> 10 % sm. shrub	> 10 % SurrTreeCover	> 25 % Forest Srnds	> 25 % EverTreeCover	> 25 % grass cover	Paddock surrounds	Bare ground	Bird bath	Forest patch > 100 ha	Coastal surrounds	Dom. strata > 8 m	Equine stock	Fencing	Impervious surfacing	Large shrub(s)	Max Veg Height > 8 m	Mudstone	Non-equine stock	Plant species richness	Remnant proximity	Sandy soils	Small tree(s)	Stock	Supp. feeding	Surrounding dam(s)	Surrounding garden(s)	Surrounding saltmarsh
Crescent honeyeater		1+			1+																1 -				1+	1+					
Eastern spinebill					1+				X -														1+					X+*			
European goldfinch									1+																						
Forest raven	1+							1+																							
Golden whistler		1+						X+*							1+	X+					1 -				X+						
Green rosella					1+							1+						1+					1+								
Grey butcherbird							X -		1+	1+	X -*										1 -				1+						1+
Grey fantail				1 -																										1 -	
House sparrow			1+		1+													X+*					1+					X+			
Little wattlebird			1+			1 -	1 -					1+						X+*					1+						1+		X+*
Masked lapwing			X+*							1+									X -							1 -					X+
Musk lorikeet	1+	1+											1 -								1 -				1 -						
Noisy miner		1+											1 -								1 -				1+						
Scarlet robin						1+														X+*				X+					1 -		
Silvereye					1+																			1 -							
Spotted pardalote	1+							1+							1+					1+											
Striated pardalote	1+					X+	1+		1 -	1 -					X+*					1+											
Superb fairy-wren					1+							1+						1+					1+								
Tasmanian native-hen			X+*			1 -	1 -									X+															
Tawny frogmouth													1 -																		

	> 10 % EverTreeCover	Ferns and graminoids	> 10 % forb cover	> 10 % ModBshSrnds	> 10 % sm. shrub	> 10 % SurrTreeCover	> 25 % Forest Srnds	> 25 % EverTreeCover	> 25 % grass cover	Paddock surrounds	Bare ground	Bird bath	Forest patch > 100 ha	Coastal surrounds	Dom. strata > 8 m	Equine stock	Fencing	Impervious surfacing	Large shrub(s)	Max Veg Height > 8 m	Mudstone	Non-equine stock	Plant species richness	Remnant proximity	Sandy soils	Small tree(s)	Stock	Supp. feeding	Surrounding dam(s)	Surrounding garden(s)	Surrounding saltmarsh
Tree martin			1+														1+														
Welcome swallow	1 -		1+			1 -	1 -			X+					1 -		1 -		1 -			X+*					1+				
Yellow-rumped thornbill			X+																			1+					X+*				
Yellow-throated honeyeater	1+						X+	X+*	1 -				1+	1-	1+					1+											

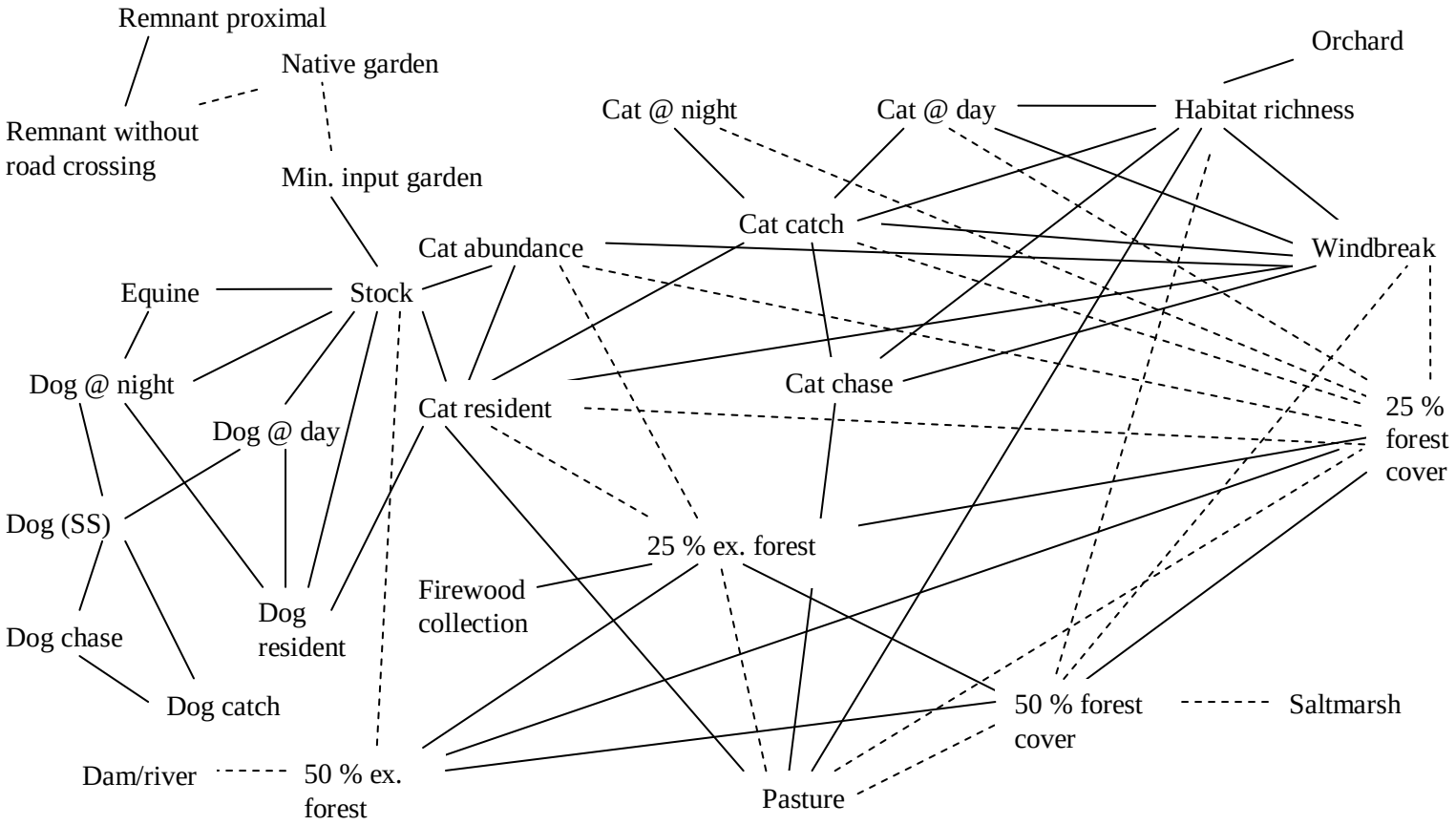
Appendix L: Explanatory power and components of predictive bird abundance models for South Arm area.

*** *P* = < 0.05, ** *P* = < 0.01, *** *P* = < 0.001**

Response variable	Independent variables	R^2
Exotic species abundance	> 10 % forb cover *, Impervious surfacing **	24.49
Native species abundance	Impervious surfacing ***, Maximum vegetation height > 8 m ***	28.56
Exotic species richness	> 10 % herb cover ***, > 25 % grass cover *	25.19
Black-headed honeyeater	> 10 % modified forest surrounds **, Maximum vegetation height > 8 m *	12.35
Common blackbird	Plant species richness ***, Surrounding saltmarsh *	28.52
Eastern spinebill	> 25 % grass cover *, Supplementary feeding **	15.45
Golden whistler	> 25 % evergreen tree cover ***, Equine stock **, Sandy soil **	35.96
Grey butcherbird	> 25 % forest surrounds **, Bare ground **	20.34
House sparrow	Impervious surfacing *, Supplementary feeding *	19.86
Little wattlebird	Impervious surfacing ***, Surrounding saltmarsh***	45.74
Masked lapwing	> 10 % forb cover *, Large shrub(s) *, Surrounding saltmarsh *	18.93
Scarlet robin	Maximum vegetation height > 8 m**, Remnant proximity **	13.35
Striated pardalote	> 10 % surrounding tree cover *, Dominant strata > 8 m **	24.77
Tasmanian native-hen	> 10 % forb cover ***, Equine stock **	24.81
Welcome swallow	> 25 % paddock surrounds **, Non-equine stock***	30.01
Yellow-rumped thornbill	> 10 % forb cover *, Stock **	14.10
Yellow-throated honeyeater	> 25 % evergreen tree cover ***, > 25 % forest surrounds **	30.41



Appendix M: Strong (*P* = < 0.01) relationships between independent variables (including habitat, landowner activity and domestic mesopredators) tested against mammalian taxa recorded in Kingborough. Solid lines indicate positive relationships, dashed lines indicate negative relationships. The bold lines represent relationships with a probability of < 0.075 and are necessary to link the constellations. SS = recorded during spotlight survey; F.O. = frequency of occurrence during SS; ex = exurban.



Appendix N: Strong (*P* = < 0.01) relationships between independent variables (including habitat, landowner activity and domestic mesopredators) tested against mammalian taxa recorded in the South Arm region. Solid lines indicate positive relationships, dashed lines indicate negative relationships. SS = recorded during spotlight survey; SS; ex = exurban.

Appendix O: Percentage frequency of occurrence of species detected during a standard duration spotlight survey (SD x 1) and surveys of lengthier durations (SD x n). Shared adjacent letters within columns and habitat types indicate no significant difference.

	Thylogale billardierii	*Pseudocheirus peregrinus*	*Trichosurus vulpecula*	*Perameles gunnii*	*Isoodon obesulus*	*Oryctolagus cuniculus*
Paddock						
SD x 1	20.00 a	0.00	20.00 a	30.00 a	0.00	60.00 a
SD x 2	20.00 a	0.00	20.00 a	30.00 a	0.00	60.00 a
SD x 3	20.00 a	0.00	20.00 a	30.00 a	0.00	60.00 a
SD x 4	20.00 a	0.00	20.00 a	30.00 a	0.00	60.00 a
SD x 5	20.00 a	0.00	20.00 a	30.00 a	0.00	60.00 a
SD x 6	20.00 a	0.00	20.00 a	30.00 a	0.00	60.00 a
SD x 7	20.00 a	0.00	20.00 a	30.00 a	0.00	60.00 a
SD x 8	20.00 a	0.00	20.00 a	40.00 a	0.00	60.00 a
SD x 9	20.00 a	0.00	20.00 a	40.00 a	0.00	60.00 a
SD x 10	20.00 a	0.00	20.00 a	40.00 a	0.00	60.00 a
Open forest						
SD x 1	10.00 a	0.00 a	20.00 a	0.00	0.00 a	20.00 a
SD x 2	10.00 a	0.00 a	20.00 a	0.00	0.00 a	20.00 a
SD x 3	10.00 a	0.00 a	20.00 a	0.00	10.00 a	20.00 a
SD x 4	10.00 a	10.00 a	20.00 a	0.00	10.00 a	20.00 a

	Thylogale billardierii	*Pseudocheirus peregrinus*	*Trichosurus vulpecula*	*Perameles gunnii*	*Isoodon obesulus*	*Oryctolagus cuniculus*
SD x 5	10.00 a	10.00 a	20.00 a	0.00	10.00 a	20.00 a
SD x 6	10.00 a	10.00 a	20.00 a	0.00	10.00 a	20.00 a
Dense forest						
SD x 1	40.00 a	10.00 a	10.00 a	0.00	0.00	20.00 a
SD x 2	40.00 a	10.00 a	20.00 a	0.00	0.00	20.00 a
SD x 3	40.00 a	10.00 a	20.00 a	0.00	0.00	20.00 a
SD x 4	40.00 a	10.00 a	20.00 a	0.00	0.00	20.00 a
SD x 5	40.00 a	10.00 a	20.00 a	0.00	0.00	20.00 a
SD x 6	40.00 a	10.00 a	20.00 a	0.00	0.00	20.00 a

The Ecological Implications of Periurban Subdivision

A survey of landowner observations, management techniques and opinions

Survey Instructions

Please read these carefully before completing the survey

It does not matter who completes this survey as long as they are resident on the participating property. You can even have multiple residents collaborate in the completion of the survey. In cases where more than one person is helping complete the survey, you have three options: you can come to a consensus on your answers; you can mark two or more boxes for the differing opinions; or you can elect a household representative, preferably the person with the most influence on your property's management, to answer the questions. The consensus option is probably the best option as it is likely that this situation of compromise is what occurs in regards to your properties management anyway.

For those of you with multiple properties adjacent to each other, and totalling more than 7 acres, remember that only the 3-7 acre property on which your house is located on was surveyed and all the questions in this survey refer to this property only.

Some questions revolve around the identification of animal species. If you are unsure of species identification, or have any other issues with the completion of the survey, then do not hesitate to call Grant Daniels on 6226 2484.

This survey will probably take you around forty-five minutes to complete. I understand that this is quite a long time, but you have a long time to complete the survey as I do not need to receive it back until the 22nd June, 2007.

Regards, Grant Daniels

Section 1: Periurban wildlife, landowner activities and attitudes

Question one will document your observations of wildlife.

Q1): For the following list of species, tick the 'Yes' box for those species that you are certain inhabit or visit your property.

	Yes
Masked owl	
Boobook owl	
Tawny frogmouth	
Australian owlet-nightjar	
Wombat	
Echidna	
Tasmanian devil	
Eastern quoll (Native cat)	
Spotted-tailed quoll (Tiger cat)	
Feral cat	
Little pygmy possum	
Eastern pygmy possum	
Brushtail possum	
Ringtail possum	
Sugar glider	
European rabbit	
European hare	
Eastern barred bandicoot	
Southern brown bandicoot	
Long-nosed potoroo	
Tasmanian bettong	
Bennett's wallaby	
Tasmanian pademelon (Rufous wallaby)	
Platypus	
Water rat	
Swamp rat	
Dusky antechinus	
Swamp antechinus	
White-footed dunnart	
Long-tailed mouse	
European rats (Black rat and Brown rat)	
House mouse	
Tiger snake	
Copperhead snake	
White-lipped (Whip) snake	
Blue-tongue lizard	
Mountain dragon	

Question two will be used to determine how changes in your local area may have led to changes in the wildlife on your property.

Q2 a) How long have you lived at your current address?

Q2 b) Referring to your property only, mark the appropriate box for how you think the species or animal groups listed in the table below have changed in abundance in your time spent at your current address.

The spare lines at the bottom of the table can be used to add other species or animal groups that you think have changed in abundance.

	Seriously declined	Declined	No change	Increased	Increased a lot	Never present	Don't know
Noisy Miner							
Magpie							
Raven (Crow)							
Superb fairy-wren							
Robins							
Native pigeons (bronzewings)							
Masked lapwing (plover)							
Native hen							
Quails							
Bassian (White's) thrush							
Blackbird							
Introduced birds (Other than blackbirds. Starling, sparrow *etc*.)							
Wombat							
Echidna							
Rabbit							
Bennett's wallaby							
Tas. pademelon							
Long-nosed potoroo							
Tasmanian bettong							
Eastern barred bandicoot							
Southern brown bandicoot							
Brushtail possum							
Ringtail possum							
Feral cat							
Blue-tongue lizard							
Snakes							
Frogs							
Butterflies							
Jackjumper ant							

Q3): For the following list of species and animal groups, tick the box that best describes your feelings about having each type of animal inhabit your property even if you don't think it is possible for such animals to live on your property.

	Very unhappy	Unhappy	Neutral	Happy	Very happy	Do not know
Bats						
Tasmanian devil						
Wallabies						
Bandicoots						
Snakes						
Blue-tongue lizard						
Brushtail possum						
Ringtail possum						
Pygmy possums						
Rabbit						
Frogs						
Butterflies						
Spiders						
Bumblebee						
Jackjumper ant						
Cockatoos						
Birds of prey						
Native cats (quolls)						
Caterpillars						
Sparrow						
Blackbird						
Small native birds (robins, wrens etc.)						
European rats						
House mouse						

Q4 a): Tick the appropriate box that refers to how frequently you experience problems (annoyance) with the following animals on your property. There are three spare lines at the beginning of the next page for you to list any other species or animal groups that you have problems with on your property.

	Daily	Weekly	Monthly	Seldom	Never	Not present
Brushtail possums						
Ringtail possums						
Wallabies						
Bandicoots						
Rabbits						
Feral cats						
Neighbours domestic stock						
Neighbours domestic cat						
Neighbours domestic dog						
Introduced birds						
Noisy miners						
Snakes						
Jackjumper ants						

Q4 a) cont.

	Daily	Weekly	Monthly	Seldom	Never

Q4 b): In the table below, state the problems that you experience with those species you marked as troublesome in Q4 a).

Examples of potential problems include: eats food intended for your cat and dog, digs holes in lawn, damages fences, eats garden plants, raids fruit trees, scares/kills wildlife, potentially dangerous to people *etc.*

If animals on your property are doing these things but you are tolerant of them and thus do not see them as a problem then do not include them in the list below.

	Problems
Brushtail possums	
Ringtail possums	
Rabbits	
Feral cats	
Neighbours domestic stock	
Neighbours domestic cat	
Neighbours domestic dog	
Introduced birds	
Noisy miners	
Wallabies	
Bandicoots	
Snakes	
Jackjumper ants	

Due to environmental changes, native animal species can become extremely abundant, leading to problems such as over-grazing of vegetation or excessive competition with less abundant species. Question five refers to hypothetical cases of over abundant native animals in parts of the urban fringe such as where you live.

Q5): Tick the appropriate box according to how strongly you agree or disagree with the following statement:

In the urban fringe, troublesome or over-abundant native animals should be . . .

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	No opinion
humanely captured and relocated.						
controlled by residents.						
controlled and monitored by local councils.						
tolerated.						
controlled *only* if they pose a threat to other native animals or to people.						
treasured; they may be abundant in some places but they are declining overall.						

Introduced species (ie. species that originate from countries other than Australia, such as rabbits, starlings, sparrows, blackbirds etc.) are present in urban areas and may compete with native animals. Ideally, potential management plans aimed at controlling introduced species in urban areas would to take into account the opinions of numerous landowners such as you.

Q6): Tick the appropriate box according to how strongly you agree or disagree with the following statements regarding introduced species.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	No opinion
They should be controlled if they out-compete native species.						
Having any type of animal on my property is better than none at all.						
All sentient beings deserve to flourish regardless of origin.						
Introduced species have no place here and should be exterminated.						

Question seven will be used to determine how landowner activities and land management practices affect wildlife on their property.

Q7): Tick the appropriate box according to how often ***you or any other resident*** participates in the activities listed below on ***your property***. For instance, you or another resident may often go wood cutting, but if you only do it on properties other than your own then you should tick the 'Never' box for that activity. If different residents do the same activity on your property but with different frequencies, then tick the box that applies to the most frequent participant only.

	Daily	Weekly	Monthly	Seldom	Never
Planting/maintaining vegetation with the intent of creating wildlife habitat.					
Planting/maintaining vegetation for other reasons (eg. vegetables, cut flowers).					
Watching wildlife.					
Watching wildlife in areas away from your home and property (eg. national parks).					
Feeding birds.					
Feeding other wildlife.					
Hunting and/or shooting animals.					
Watching television programs about nature.					
Reading books about nature.					
Pesticide application.					
Herbicide application (eg. glyphosate).					
Fertiliser application.					
Trapping and relocating brushtail possums.					
Trapping and relocating other native animals.					
Releasing animals captured or rescued from other areas.					
Cutting trees for firewood.					
Paying someone else to maintain your property/garden.					

Question eight will be used to determine the potential effects your pets may be having on wildlife in the urban fringe.

Q8: a) Do you keep pet cats on your property (Yes or No)?

If 'Yes'→ 8 b) and c)

If 'No' → Q8 d)

b) How many?

c) In the table below, tick the box appropriate to how often you think your cat(s) . . .

	Daily	Weekly	Monthly	Seldom	Never	Can't be sure
catches wildlife.						
chases and harasses wildlife.						
remains outside and unrestrained during the day.						
remains outside and unrestrained at night.						
List the species you think your cat has caught (be as specific as you can):						

Q8: d) Do you keep pet dogs on your property (Yes or No)?

If 'Yes'→ 8 e), f) and g)

If 'No' → Q9

e) How many?

f) What breed(s) are they?*

*(If you are unaware of your dogs breed, or it is a cross-breed, then state if it is small (< 30 cm), medium (30 – 60 cm) or large (> 60 cm) – measured to shoulder height from ground).

g) In the table below, tick the box appropriate to how often you think your dog(s). . .

	Daily	Weekly	Monthly	Seldom	Never	Can't be sure
catches wildlife.						
chases and harasses wildlife.						
remains outside and unrestrained during the day.						
remains outside and unrestrained at night						
List the species you think your dog has caught (be as specific as you can):						

Part of our research is aimed at determining the importance of trees to wildlife. This includes understanding what people in urban areas think about having trees on their property.

Q9): Regardless of whether you have trees close to your home or not, state how strongly you agree or disagree with the following statements regarding trees growing in close proximity (25 m) to your home. In this case, consider any woody plant 8 m or greater in height to be a tree.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	No opinion
Trees harbour nuisance animals and so I don't like them near my home.						
Falling limbs are too dangerous a risk to have trees near the home.						
Trees are a symbol of wealth and prosperity.						
Trees increase real estate prices.						
Trees provide vital habitat for native animals.						
Trees give me shelter and privacy.						
Trees are too hard to control.						
Trees create unwanted mess.						
Trees cast too much shade.						
Trees provide useful shade from summer heat.						
Trees are too serious a fire hazard to have near the home.						
Trees are good for the environment.						
Trees provide cover for robbers.						
Tree roots wreck drains and drives.						
Trees are a hassle because their leaves block roof guttering						

People's attitudes towards conservation issues could have an influence on the way they manage their properties and therefore the wildlife that is found on them. Questions ten and eleven are intended to further establish your opinions as a landowner, which can then be compared with the wildlife we have recorded on your property.

Q10): Tick the appropriate box in order to state how strongly you agree or disagree with the statements listed in the table below.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	No opinion
People living in and near the bush should have minimal impact on native animals.						
I wish it was easier to clear bush to create more paddocks for stock.						
The feeding of wild animals is fine in moderation.						
Dogs are a threat to wildlife in the urban fringe.						
Cats are a threat to wildlife in the urban fringe.						

Q11): Tick the appropriate box according to ***if you would be willing to*** . . .

	Yes	No	Maybe
pay a conservation agency to undertake conservation orientated work on your land.			
allow a conservation agency to undertake conservation orientated work on your land if you were compensated adequately.			
allow a commercial agency to harvest trees on your property if you were compensated adequately.			
change your land management practices if you were informed of potentially better practices for wildlife.			

If the periurban fringe is important for native wildlife then it is important that we understand what is drawing people to this type of area and if they are likely to continue to live in similar areas. Questions twelve and thirteen address this issue.

Q12): By ticking the appropriate box, state how important you feel the following aspects are in making somewhere a nice place to live.

	Not important at all	Slightly important	Reasonably important	Very important
A place that has the potential to provide me with a source of income.				
A place that is a haven for wildlife.				
A place that has space for children to play.				
A place that has space for domestic animals.				
A place where I can harvest firewood.				
A place where I can grow fruit and vegetables.				
A place where I can undertake passive recreation (eg. gardening, camping, hiking).				
A place where I can undertake active recreation (eg. motorcycle riding, tree cutting).				
A place where I can be close to nature and wildlife.				
A place that is close to the city.				
An area that has cheap real estate.				
A place that has a romantic, country-feel.				
A place with nice environmental conditions (temperature, rainfall).				
A place with lots of natural bushland nearby.				
Being surrounded by like-minded neighbours.				

Q13 a): How long do you intend to stay at your current address?

Q13 b): This question involves the hypothetical scenario of you moving home. By ticking the appropriate boxes in the table below, state how likely is it that ***your next property would be . . .***

	Very unlikely	**Unlikely**	**Maybe**	**Likely**	**Very likely**
another periurban property					
more urbanised:					
▪ Suburban					
▪ Urban/city					
less urbanised:					
▪ Rural/agricultural					
▪ Remote bush					

Section 2: Information about yourself

Q1): In regards to your current dwelling, circle the option that best describes your situation?

- Renter / tenant
- Owner

Q2): What is your gross household weekly income? (Circle one option)

- $1 - $149 ($1 - $7,799 per year)
- $150-$249 ($7,800 - $12,999 per year)
- $250-$399 ($13,000 – $20,799 per year)
- $400-$599 ($20,800 - $31,199 per year)
- $600-$799 ($31,200 - $41,599 per year)
- $800-$999 ($41,600 - $51,999 per year)
- $1,000-$1,299 ($52,000 - $67,599 per year)
- $1,300-$1,599 ($67,600 - $83,199 per year)
- $1,600-$1,999 ($83,200 - $103,999 per year)
- $2,000 or more ($104,000 or more per year)

Q3): Circle the option that describes the level of education that the most educated person living on your property has completed?

- Primary
- Secondary
- College (year 12)
- Technical / Trade Certificate
- Tertiary degree / Diploma
- Postgraduate degree

Q4): Circle each age group for which a resident on your property belongs to? (For age groups in which there are multiple residents, place the number of individuals in the brackets following the age group.)

- 18 years or less ( )
- 19 – 24 years ( )
- 25 – 34 years ( )
- 35 – 44 years ( )
- 45 – 54 years ( )
- 55 – 64 years ( )
- 65 – 74 years ( )
- 75 or more years ( )

Q5 a): How many female adults reside on your property?

b): How many male adults reside on your property?

Q6): In case I have any queries regarding survey responses, please list the names of the people that participated in answering this survey:

Q7): Please write your property address here:

Thankyou for completing this survey.

Further comments: If you have any additional observations or opinions that you think may prove useful, please use this space to list them.

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Appendix Q: Variation in the survey responses of exurbanite assemblages

	Biophiles	Autocrats	Idealists	Utilitarians	*P*
Q3 bats	**4.7917**	3.7647	4.5	4	0.002
Q3 devil	**4.6087**	3.4615	4.3571	3.8333	0.001
Q3 wallabies	**4.2917**	3.9375	3.4615	3.7857	0.104
Q3 bandicoots	**4.88**	4.1875	4.5714	4.0714	0.002
Q3 snakes	**3.72**	2.778	3.571	2.4	0.001
Q3 blue-tongue lizard	**4.92**	4.5	4.6429	4.0667	0.001
Q3 brushtail possum	**3.8333**	2.8333	2.7857	3.5333	0.002
Q3 ringtail possum	**4.625**	3.8824	4	3.6429	0.004
Q3 pygmy possum	**4.8696**	4	4.2857	4	0.002
Q3 frog	**4.96**	4.6667	4.7857	4.5333	0.061
Q3 butterflies	**4.96**	4.6111	4.6429	4.4667	0.015
Q3 spiders	**4.4**	3.3889	3.8571	3.2667	0.000
Q3 jackjumper	**2.84**	1.444	2.5	2.067	0.001
Q3 cockatoo	**4.88**	3.8333	3.9286	4.0714	0.000
Q3 raptors	**4.88**	4.2941	4.5714	3.9333	0.002
Q3 quolls	**4.7917**	3.6875	4.4286	3.9286	0.000
Q3 caterpillar	**4.375**	3.2222	3.7143	3.8667	0.000
Q3 small native birds	**4.96**	4.6667	4.8571	4.6	0.039
Q4 ringtail possum	**4.5789**	4.4667	4.6154	4.1429	0.498
Q4 noisy miners	**4.4**	3.917	3.5	4.167	0.411
Q5 controlled by councils	**3.19**	3.111	3	3	0.963
Q5 tolerated	**3.9091**	2.875	3.5	3.6	0.011
Q5 only controlled if threat	**4.44**	4	3.5714	4.1538	0.072
Q5 treasured	**4.2727**	3.4706	3	3.8	0.002
Q6 competing with natives	**4.417**	4.389	4.071	4.375	0.754
Q7 creating habitat	**3.26**	2.667	3	2	0.005
Q7 watch wildlife at home	**4.88**	4.3056	4.1429	4.125	0.022
Q7 watching wildlife elsewhere	**3**	2.4444	2.7143	2.25	0.024
Q7 watch wildlife on television	**3.4**	3.1667	3.3571	3.25	0.809
Q7 reading about nature	**3.3**	2.2778	2.5714	2.375	0.000
Q7 releasing animals	**1.1667**	**1.1667**	1	1.0625	0.340
Q9 trees increase real estate	**3.3636**	3	3.25	2.5	0.039
Q9 trees are wildlife habitat	**4.92**	4.6111	4.7857	4.5	0.014
Q9 trees provide privacy	**4.76**	4.3889	4.5	4.375	0.038
Q9 tree shade welcomed	**4.64**	4.2222	3.9286	4.3125	0.002
Q10 bush residents should have no impact	**4.68**	4.0556	4.3571	3.8125	0.010
Q11 pay conservation agency	**1.6**	1.3333	1.3571	1.1875	0.103
NPTL - haven for wildlife	**3.72**	2.9444	3.0714	2.875	0.000

NPTL - fruit and vegetable gardening	**2.92**	2.556	2.643	2.5	0.552
NPTL - passive recreation	**3.36**	3.0556	3.1429	3.125	0.636
NPTL - close to wildlife and nature	**3.92**	3.1667	3.7143	3.1875	0.001
NPTL - romantic, country feel	**2.8**	2.5	1.8214	2.5625	0.012
NPTL - proximity to bushland	**3.76**	3.1111	3.6429	3.3125	0.003
NPTL - likeminded neighbours	**3.28**	3	2.6786	3.0625	0.216
Q13 next address – exurbia	**4.174**	3.438	3.25	3.857	0.181
Q4 neighbours dog	3.478	**4.235**	3.929	4.133	0.137
Q5 capture and relocate	3.45	**3.824**	3.214	3.75	0.416
Q5 controlled by residents	1.4091	**1.9444**	1.7857	1.7	0.385
Q6 all sentient beings deserve to flourish	2.5217	**2.5294**	1.7857	2.3846	0.121
Q7 gardening	3.34	**3.389**	3.071	2.182	0.397
Q7 feeding birds	2.96	**2.972**	1.154	2.438	0.001
Q7 feeding wildlife other than birds	2.2	**2.5**	1	2.0762	0.012
Q7 pesticide application	1.24	**1.6111**	1.2857	1.4667	0.159
Q7 herbicide application	1.56	**1.9444**	1.7857	1.4667	0.136
Q7 fertiliser application	1.92	**2.1111**	1.9286	1.7333	0.591
Q7 trapping brushtail possums	1.28	**1.7778**	1.2857	1.125	0.097
Q7 trapping other species	1.08	**1.2222**	1	1.0625	0.171
Q7 firewood collection	1.64	**2.0278**	1.7143	1.875	0.387
Q8 small dog abundance	0.08	**0.2222**	0.2143	0.1875	0.649
Q8 large dog abundance	0.2083	**0.6667**	0.3077	0.4	0.093
Q9 trees harbour nuisances	1.2	**2.1667**	1.5	1.5625	0.000
Q9 trees limb damage	2.583	**3.333**	2.429	2.933	0.104
Q9 trees symbolise wealth	2.25	**2.467**	1.923	2.188	0.663
Q9 trees too hard to control	1.2917	**2.3333**	1.7857	1.6875	0.000
Q9 trees create mess	1.6	**2.8333**	2.5	1.875	0.000
Q9 trees create too much shade	1.68	**2.6667**	2.4286	2.125	0.000
Q9 trees are a fire hazard	2.76	**3.639**	2.786	3.188	0.125
Q9 trees reduce home security	1.8636	**3.2353**	2.2308	2.125	0.000
Q9 trees damage infrastructure	2.8261	**3.7059**	3.0714	2.875	0.007
Q9 tree leaves block guttering	2.4167	**3.3889**	3.3571	2.5625	0.001
Q11 allow conservation if compensated	2.48	**2.5**	2.0714	1.8	0.012
NPTL - harvest firewood	1.44	**1.6667**	1.2857	1.4	0.554
Q13 next address – suburban	1.76	**2.733**	2.083	2.214	0.097
Q13 next address – city	1.625	**2.412**	2.077	1.417	0.111
Q4 snakes	4.2917	4.2222	**4.3077**	4.2	0.902
Q4 jackjumper	3.625	2.824	**4.077**	3.333	0.041
Q4 bandicoots	4.7727	4.6	**4.9231**	4.8	0.491
Q6 exotics should be exterminated	3.146	3.029	**3.429**	2.615	0.376
Q7 hunt wildlife	1.12	1.0556	**1.3846**	1.1875	0.318
Q8 cat unrestrained @ day	3.444	3.429	**5**	4.625	0.260
Q8 cat unrestrained @ night	2.222	2.857	**5**	2.625	0.143
Q8 dog catches wildlife	1.5	1.333	**2.2857**	1.3571	0.012
Q8 dog chases wildlife	2.364	1.417	**3.857**	2.077	0.000

Q9 trees good for the environment	4.72	4.6111	**4.8571**	4.375	0.258
Q10 dogs are a threat to wildlife	4.32	3.5	**4.4286**	2.6875	0.000
Q10 cats are a threat to wildlife	4.84	4.7778	**4.9286**	3.75	0.000
Q11 willingness to change land practices	2.8	2.6111	**2.8571**	2.3125	0.028
NPTL - cheap real estate	1.68	1.6667	**1.9286**	1.8667	0.753
NPTL - nice environmental conditions	3.28	3	**3.3571**	3.1875	0.436
NPTL - close to the city	2.44	2.3889	**2.6429**	2.3333	0.766
Q13 next address - remote bush	2.75	1.733	**3.308**	2.417	0.018
Q3 rabbit	1.56	1.4444	1.4286	**2.6**	0.000
Q3 bumblebee	3.56	3.333	3.5	**3.9**	0.475
Q3 sparrow	2.375	2.333	1.786	**3.333**	0.003
Q3 blackbird	2.375	2.111	1.571	**2.929**	0.009
Q3 rats	1.52	1.3333	1	**2.1429**	0.001
Q3 mouse	1.72	1.6667	1.2143	**2**	0.107
Q4 brushtail possum	3.44	2.889	3.643	**3.933**	0.145
Q4 rabbits	2.24	2.5	2.643	**3.533**	0.054
Q4 neighbours stock	4.3333	4.0909	4.5	**4.5714**	0.404
Q4 neighbours cat	3.143	3.643	4	**4.8**	0.001
Q4 exotic birds	3.917	3.222	3	**4.25**	0.032
Q6 any animal is fine	2.174	2.765	2.143	**3.154**	0.046
Q7 hire garden help	1	1.0556	1	**1.25**	0.049
Q8 cat(s) resident	0.36	0.3889	0.2143	**0.5625**	0.279
Q8 cat abundance	0.52	0.5294	0.2143	**0.875**	0.132
Q8 cat catches wildlife	2.667	2.571	2.333	**3.25**	0.553
Q8 cat chases wildlife	2.625	2.8	3	**3.5**	0.828
Q8 dog(s) resident	0.52	0.7778	0.5385	**0.9375**	0.018
Q8 dog abundance	0.52	1.1667	0.7143	**1.1875**	0.005
Q8 medium dog abundance	0.2917	0.2914	0.2308	**0.625**	0.226
Q8 dog unrestrained @ day	3.583	2	3.714	**4.143**	0.013
Q8 dog unrestrained @ night	2.083	1.077	2.286	**2.4**	0.137
Q10 desire to clear more land	1.24	2.125	1.5714	**2.375**	0.000
Q10 feeding wildlife is fine	2.68	2.889	1.571	**2.938**	0.001
NPTL - provides income	1.16	1.1667	1.4643	**1.8**	0.032
NPTL - space for kids to play	3.08	3.111	2.714	**3.656**	0.088
NPTL - space for livestock	2.36	2.6667	1.8571	**3.3125**	0.000
Q11 allow commercial forestry	1.04	1.1111	1	**1.25**	0.251
NPTL - active recreation	1.16	1.6667	1.6429	**2.1333**	0.011
Q13 next address – rural	2.609	2.25	2.923	**3.083**	0.352

Appendix R: Wildlife taxa reported (by residents) and recorded (during spotlight surveys) on the properties of people assemblages.

	Biophiles	Autocrats	Idealists	Utilitarians	P
Both regions					
Reported by landowners					
Echidna	52.00 a	66.67 a	78.57 a	56.25 a	0.381
Masked owl	8.00 a	22.22 a	21.43 a	12.50 a	0.528
Boobook owl	32.00 a	11.11 a	28.57 a	6.25 a	0.136
Australian owlet-nightjar	20.00 a	5.56 a	0.00 a	0.00 a	N/A
Tawny frogmouth	36.00 a	44.44 a	64.29 a	50.00 a	0.392
Wombat	4.00 a	0.00 a	7.14 a	6.25 a	N/A
Tasmanian devil	4.00 a	5.56 a	7.14 a	12.50 a	0.901
Quolls	20.00 a	5.56 a	14.29 a	12.50 a	0.599
Brushtail possum	100.00 a	100.00 a	100.00 a	87.50 a	N/A
Feral cat	60.00 a	27.78 a	57.14 a	31.25 a	0.090
Pygmy possums	8.00 a	11.11 a	7.14 a	0.00 a	N/A
Ringtail possum	52.00 a	66.67 ab	85.71 b	43.75 a	0.085
Sugar glider	16.00 a	11.11 a	21.43 a	12.50 a	0.858
European rabbit	100.00 a	88.90 a	100.00 a	100.00 a	N/A
Eastern barred bandicoot	72.00 a	44.44 ab	64.29 ab	25.00 b	0.019
Southern brown bandicoot	52.00 a	27.78 a	21.43 a	43.75 a	0.194
Macropods	36.00 a	38.89 a	57.14 a	31.25 a	0.493
Potoroids	24.00 a	44.44 a	35.71 a	25.00 a	0.479

	Biophiles	Autocrats	Idealists	Utilitarians	P
Platypus	0.00 a	5.56 ab	21.43 b	6.25 ab	N/A
Mus musculus	92.00 a	88.89 a	100.00 a	93.75 a	N/A
European Rattus	36.00 a	38.89 a	85.71 b	50.00 ab	0.019
Snakes	92.00 a	88.89 a	85.71 a	87.50 a	0.936
Blue-tongue lizard	88.00 a	100.00 a	78.57 a	100.00 a	0.080
Mountain dragon	16.00 a	5.56 a	0.00 a	12.50 a	0.367
Spotlighted					
Total species richness	3.875 a	3.471 a	3.846 a	3.312 a	0.613
Possums and gliders [a]	3.583 a	3.412 a	3.385 a	3.063 a	0.903
Possums and gliders [b]	100.00 a	88.24 a	92.31 a	87.50 a	N/A
Macropods [a]	1.542 a	1.294 a	2.231 a	1.375 a	0.706
Macropods [b]	29.17 a	35.29 a	53.85 a	37.50 a	0.525
Potoroids [a]	0.5417 a	0.7059 a	0.5385 a	0.5000 a	0.558
Potoroids [b]	29.17 a	41.18 a	38.46 a	31.25 a	0.849
Peramelids [a]	2.000 a	1.529 a	1.154 a	1.937 a	0.419
Peramelids [b]	79.17 a	64.71 a	69.23 a	62.50 a	0.655
M. rufogriseus [a]	0.0833 a	0.1765 a	0.2308 a	0.0000 a	0.679
M. rufogriseus [b]	4.17 a	5.88 a	7.69 a	0.00 a	N/A
T. billardierii [a]	1.458 a	1.118 a	2.000 a	1.375 a	0.768
T. billardierii [b]	29.17 a	29.41 a	46.15 a	37.50 a	0.249
P. breviceps [a]	0.0417 a	0.0000 a	0.0000 a	0.1250 a	0.274
P. breviceps [b]	4.17 a	0.00 a	0.00 a	12.50 a	N/A
P. peregrinus [a]	0.5833 a	0.4118 a	0.7692 a	0.2500 a	0.450
P. peregrinus [b]	37.50 a	29.41 a	30.77 a	18.75 a	0.656
T. vulpecula [a]	2.958 a	3.000 a	2.615 a	2.688 a	0.921
T. vulpecula [b]	95.83 a	82.35 a	92.31 a	81.25 a	0.403
P. gunnii [a]	1.583 a	1.059 a	0.923 a	1.375 a	0.443

	Biophiles	Autocrats	Idealists	Utilitarians	P
P. gunnii [b]	29.17 a	47.06 a	53.85 a	56.25 a	0.463
I. obesulus [a]	0.4167 a	0.4706 a	0.2308 a	0.5625 a	0.700
I. obesulus [b]	25.00 a	41.18 a	15.38 a	37.50 a	0.384
B. gaimardi [a]	0.3750 a	0.2353 a	0.3077 a	0.1250 a	0.717
B. gaimardi [b]	20.83 a	17.65 a	23.07 a	12.50 a	0.884
P. tridactylus [a]	0.1667 a	0.4706 a	0.2308 a	0.3750 a	0.500
P. tridactylus [b]	12.50 a	29.41 a	23.08 a	18.75 a	0.598
O. cuniculus [a]	3.417 a	2.059 a	3.308 a	2.500 a	0.132
O. cuniculus [b]	87.50 a	70.59 a	92.31 a	62.50 a	0.128
F. catus [a]	0.7500 a	0.4706 a	0.3846 a	0.9375 a	0.327
F. catus [b]	41.67 a	29.41 a	38.46 a	50.00 a	0.682
C. f. familiaris [a]	0.208 a	0.294 ab	0.154 ab	1.188 b	0.034
C. f. familiaris [b]	8.33 a	17.65 ab	15.38 ab	37.50 b	0.136
Tawny frogmouth [a]	0.0833 a	0.2353 a	0.1538 a	0.3125 a	0.641
Tawny frogmouth [b]	4.17	11.76	7.69	18.75	0.493
Intra-regional					
Kingborough					
Reported by landowners					
Echidna	60.00 a	75.00 a	62.50 a	42.86 a	0.652
Masked owl	0.00 a	25.00 a	25.00 a	14.29 a	0.392
Boobook owl	50.00 a	25.00 a	37.50 a	14.29 a	0.439
Australian owlet-nightjar	10.00 a	0.00 a	0.00 a	0.00 a	N/A
Tawny frogmouth	30.00 a	25.00 a	62.50 a	28.57 a	0.367
Wombat	10.00 a	0.00 a	12.50 a	0.00 a	N/A
Tasmanian devil	20.00 a	12.50 a	12.50 a	14.29 a	0.965
Quolls	30.00 a	0.00 a	25.00 a	0.00 a	0.172
Brushtail possum	100.00 a	100.00 a	100.00 a	85.70 a	N/A

	Biophiles	Autocrats	Idealists	Utilitarians	P
Feral cat	70.00 a	37.50 a	75.00 a	28.57 a	0.161
Pygmy possums	10.00 a	25.00 a	12.50 a	0.00 a	N/A
Ringtail possum	40.00 a	50.00 a	75.00 a	28.57 a	0.301
Sugar glider	20.00 a	12.50 a	25.00 a	14.29 a	0.915
European rabbit	100.00 a	100.00 a	100.00 a	100.00 a	N/A
Eastern barred bandicoot	80.00 a	62.50 ab	75.00 ab	28.57 b	0.149
Southern brown bandicoot	10.00 a	12.50 a	12.50 a	42.86 a	0.300
Macropods	80.00 a	87.50 a	100.00 a	57.14 a	0.184
Potoroids	40.00 a	50.00 a	50.00 a	28.57 a	0.813
Platypus	0.00 a	12.50 a	37.50 a	14.29 a	0.176
Mus musculus	80.00 a	75.00 a	100.00 a	85.71 a	0.528
European rattus	50.00 a	37.50 a	87.50 a	57.14 a	0.213
Snakes	90.00 a	87.50 a	75.00 a	71.43 a	0.710
Blue-tongue lizard	70.00 a	100.00 a	62.50 a	100.00 a	0.099
Mountain dragon	20.00 a	0.00 a	0.00 a	0.00 a	N/A
Spotlighted					
Total species richness	4.444 a	4.714 a	4.625 a	3.571 a	0.501
Possums and gliders [a]	3.889 a	3.429 a	3.125 a	2.000 a	0.467
Possums and gliders [b]	100.00 a	85.71 a	87.50 a	71.43 a	N/A
Macropods [a]	3.889 a	3.143 a	3.625 a	3.143 a	0.902
Macropods [b]	66.67 a	85.71 a	87.50 a	85.71 a	0.660
Potoroids [a]	1.111 a	1.429 a	0.750 a	0.714 a	0.558
Potoroids [b]	55.56 a	85.71 a	50.00 a	42.86 a	0.377
Peramelids [a]	1.444 a	1.857 a	1.500 a	2.000 a	0.900
Peramelids [b]	77.78 a	71.43 a	87.50 a	42.86 a	0.267
M. rufogriseus [a]	0.2222 a	0.4286 a	0.3750 a	0.0000 a	0.774
M. rufogriseus [b]	11.11 a	14.29 a	12.50 a	0.00 a	N/A

	Biophiles	Autocrats	Idealists	Utilitarians	P
T. billardierii [a]	3.667 a	2.714 a	3.250 a	3.143 a	0.897
T. billardierii [b]	66.67 a	71.43 a	75.00 a	85.71 a	0.854
P. breviceps [a]	0.1111 a	0.0000 a	0.0000 a	0.0000 a	0.506
P. breviceps [b]	11.11 a	0.00 a	0.00 a	0.00 a	N/A
P. peregrinus [a]	0.889 a	0.571 a	0.875 a	0.143 a	0.547
P. peregrinus [b]	33.33 a	42.86 a	37.50 a	14.29 a	0.682
T. vulpecula [a]	2.889 a	2.857 a	2.250 a	1.857 a	0.674
T. vulpecula [b]	100.00 a	85.71 a	87.50 a	71.43 a	N/A
P. gunnii [a]	1.444 a	1.429 a	1.500 a	1.286 a	0.933
P. gunnii [b]	77.78 a	57.14 a	87.50 a	42.86 a	0.242
I. obesulus [a]	0.0000 a	0.4286 a	0.0000 a	0.7143 a	0.062
I. obesulus [b]	0.00 a	42.90 a	0.00 a	42.90 a	0.029
B. gaimardi [a]	0.8889 a	0.5714 a	0.5000 a	0.1429 a	0.479
B. gaimardi [b]	44.44 a	42.86 a	37.50 a	14.29 a	0.600
P. tridactylus [a]	0.2222 a	0.8571 a	0.2500 a	0.5714 a	0.335
P. tridactylus [b]	22.22 a	57.14 a	25.00 a	28.57 a	0.451
O. cuniculus [a]	2.778 a	2.143 a	3.875 a	2.429 a	0.275
O. cuniculus [b]	77.78 a	71.43 a	100.00 a	71.43 a	0.435
F. catus [a]	0.4444 a	1.0000 a	0.5000 a	0.5714 a	0.504
F. catus [b]	22.22 a	57.14 a	50.00 a	42.86 a	0.509
C. f. familiaris [a]	0.1111 a	0.5714 a	0.2500 a	0.4286 a	0.465
C. f. familiaris [b]	11.11 a	28.57 a	25.00 a	28.57 a	0.803
Tawny frogmouth [a]	0.1111 a	0.2857 a	0.2500 a	0.1429 a	0.916
Tawny frogmouth [b]	11.11 a	14.29 a	12.50 a	14.29 a	N/A
Mean bird species richness (BSR) and plant species richness (PSR) within exurban habitats					
Exurban forest BSR	11.286 a	13.000 a	10.500 a	9.500 a	0.619

	Biophiles	Autocrats	Idealists	Utilitarians	P
Exurban forest native BSR	10.857 a	12.200 a	10.500 a	8.500 a	0.566
Exurban forest exotic BSR	0.4286 a	0.8000 a	0.000 a	1.000 a	0.482
Exurban forest PSR	26.143 a	24.600 a	25.000 a	29.000 a	0.868
Modified forest BSR	10.500 a	17.000 a	13.250 a	11.800 a	0.209
Modified forest native BSR	10.500 a	15.250 a	12.250 a	11.000 a	0.259
Modified forest exotic BSR	0.000 a	1.750 a	1.000 a	0.800 a	0.354
Modified forest PSR	26.50 a	42.50 a	40.50 a	25.60 a	0.292
Garden BSR	12.167 a	10.000 a	11.714 a	16.000 a	0.787
Garden native BSR	11.000 a	9.000 a	9.286 a	14.000 a	0.657
Garden exotic BSR	1.167 a	1.000 a	2.429 a	2.000 a	0.222
Garden PSR	67.667 a	55.000 a	71.000 a	46.000 a	0.772
Paddock BSR	4.500 a	6.333 a	5.667 a	3.667 a	0.607
Paddock native BSR	3.500 a	5.000 a	4.667 a	2.667 a	0.480
Paddock exotic BSR	1.000 a	1.333 a	1.000 a	1.000 a	0.945
Paddock PSR	15.000 a	26.000 a	16.000 a	16.667 a	0.324
South Arm					
Reported					
Echidna	46.67 a	60.00 ab	100.00 b	66.67 ab	0.151
Masked owl	13.33 a	20.00 a	16.67 a	11.11 a	N/A
Boobook owl	20.00 a	0.00 a	16.70 a	0.00 a	N/A
Australian owlet-nightjar	20.00 a	10.00 a	0.00 a	0.00 a	N/A
Tawny frogmouth	40.00 a	60.00 a	66.67 a	66.67a	0.515
Wombat	0.00 a	0.00 a	0.00 a	11.11 a	N/A
Tasmanian devil	0.00 a	0.00 a	0.00 a	11.10 a	N/A
Quolls	13.33 a	10.00 a	0.00 a	22.22 a	N/A
Brushtail possum	100.00 a	100.00 a	100.00 a	88.90 a	N/A
Feral cat	53.33 a	20.00 a	33.33 a	33.33 a	0.388
Pygmy possums	6.67 a	0.00 a	0.00 a	0.00 a	N/A

	Biophiles	Autocrats	Idealists	Utilitarians	P
Ringtail possum	60.00 a	80.00 a	100.00 a	55.56 a	0.199
Sugar glider	13.33 a	10.00 a	16.67 a	11.11 a	N/A
European rabbit	100.00 a	80.00 a	100.00 a	100.00 a	N/A
Eastern barred bandicoot	66.67 a	30.00 a	50.00 a	22.22 a	0.127
Southern brown bandicoot	80.00 a	40.00 a	33.33 a	44.44 a	0.100
Macropods	6.67 a	0.00 a	0.00 a	11.11 a	N/A
Potoroids	13.33 a	40.00 a	16.67 a	22.22 a	0.458
Platypus	0.00 a	0.00 a	0.00 a	0.00 a	N/A
Mus musculus	100.00 a	100.00 a	100.00 a	100.00 a	N/A
European rattus	26.67 a	40.00 ab	83.33 b	44.44 ab	0.129
Snakes	93.33 a	90.00 a	100.00 a	100.00 a	N/A
Blue-tongue lizard	100.00 a	100.00 a	100.00 a	100.00 a	N/A
Mountain dragon	13.33 a	10.00 a	0.00 a	22.22 a	N/A
Spotlighted					
Total species richness	3.533 a	2.600 a	2.600 a	3.111 a	0.195
Possums and gliders [a]	3.400 a	3.400 a	3.800 a	3.889 a	0.920
Possums and gliders [b]	93.33 a	80.00 a	100.00 a	88.89 a	N/A
Macropods [a]	0.133 a	0.000 a	0.000 a	0.000 a	0.676
Macropods [b]	6.67 a	0.00 a	0.00 a	0.00 a	N/A
Potoroids [a]	0.200 a	0.200 a	0.200 a	0.333 a	0.952
Potoroids [b]	13.33 a	10.00 a	20.00 a	22.22 a	N/A
Peramelids [a]	2.333 a	1.300 a	0.600 a	1.889 a	0.141
Peramelids [b]	80.00 a	60.00 a	40.00 a	77.78 a	0.317
M. rufogriseus [a]	0.000 a	0.000 a	0.000 a	0.000 a	N/A
M. rufogriseus [b]	0.00 a	0.00 a	0.00 a	0.00 a	N/A
T. billardierii [a]	0.133 a	0.000 a	0.000 a	0.000 a	0.676
T. billardierii [b]	6.67 a	0.00 a	0.00 a	0.00 a	N/A

	Biophiles	Autocrats	Idealists	Utilitarians	P
P. breviceps [a]	0.000 a	0.000 a	0.000 a	0.222 a	0.070
P. breviceps [b]	0.00 a	0.00 a	0.00 a	22.22 a	N/A
P. peregrinus [a]	0.4000 a	0.3000 a	0.6000 a	0.3333 a	0.893
P. peregrinus [b]	40.00 a	20.00 a	20.00 a	22.22 a	0.640
T. vulpecula [a]	3.000 a	3.100 a	3.200 a	3.333 a	0.982
T. vulpecula [b]	93.33 a	80.00 a	100.00 a	88.89 a	N/A
P. gunnii [a]	1.667 a	0.800 a	0.000 a	1.444 a	0.063
P. gunnii [b]	66.67 a	40.00 ab	0.00 b	66.67 a	0.045
I. obesulus [a]	0.6667 a	0.5000 a	0.6000 a	0.4444 a	0.926
I. obesulus [b]	40.00 a	40.00 a	40.00 a	33.33 a	0.988
B. gaimardi [a]	0.0667 a	0.0000 a	0.0000 a	0.1111 a	0.697
B. gaimardi [b]	6.67 a	0.00 a	0.00 a	11.11 a	N/A
P. tridactylus [a]	0.1333 a	0.2000 a	0.2000 a	0.2222 a	0.983
P. tridactylus [b]	6.67 a	10.00 a	20.00 a	11.11 a	N/A
O. cuniculus [a]	3.800 a	2.000 a	2.400 a	2.556 a	0.201
O. cuniculus [b]	93.33 a	70.00 ab	80.00 ab	55.56 b	0.180
F. catus [a]	0.9333 a	0.1000 a	0.2000 a	1.2222 a	0.056
F. catus [b]	53.33 a	10.00 b	20.00 ab	55.56 a	0.084
C. f. familiaris [a]	0.267 a	0.100 a	0.000 a	1.778 a	0.033
C. f. familiaris [b]	6.67 a	10.00 ab	0.00 ab	44.44 b	N/A
Tawny frogmouth [a]	0.0677 a	0.2000 a	0.0000 a	0.4444 a	0.449
Tawny frogmouth [b]	6.67 a	10.00 a	0.00 a	22.22 a	N/A
Mean bird species richness (BSR) and plant species richness (PSR) within exurban habitats					
Exurban forest BSR	5.500 a	7.667 a	7.000 a	11.000 a	0.638
Exurban forest native BSR	5.500 a	7.500 a	7.000 a	11.000 a	0.640
Exurban forest exotic BSR	0.000 a	0.167 a	0.000 a	0.000 a	0.689

	Biophiles	Autocrats	Idealists	Utilitarians	P
Exurban forest PSR	26.500 a	19.833 a	26.600 a	29.000 a	0.147
Modified forest BSR	7.857 a	9.167 a	9.000 a	14.667 a	0.154
Modified forest native BSR	7.571 a	8.667 a	8.000 a	13.667 a	0.148
Modified forest exotic BSR	0.286 a	0.500 a	1.000 a	1.000 a	0.518
Modified forest PSR	36.000 a	26.500 a	29.500 a	23.333 a	0.471
Garden BSR	10.000 a	9.000 a	11.000 a	9.000 a	0.988
Garden native BSR	8.333 a	8.000 a	9.000 a	7.500 a	0.994
Garden exotic BSR	1.667 a	1.000 a	2.000 a	1.500 a	0.919
Garden PSR	107.170 a	66.750 a	109.000 a	45.000 a	0.533
Paddock BSR	6.000 a	5.000 a	3.000 a	4.800 a	0.819
Paddock native BSR	4.857 a	5.000 a	3.000 a	4.200 a	0.873
Paddock exotic BSR	1.143 a	0.000 a	0.000 a	0.600 a	0.705
Paddock PSR	18.857 a	29.000 a	17.000 a	15.600 a	0.434

[a] Frequency of occurrence

[b] Percentage distribution (properties)

Appendix S: Percentage of cat and dog owners that reported various species and life forms as the prey of their pets. Shared adjacent letters within each row indicate no significant difference.

	Cats in Kingborough	Dogs in Kingborough	Cats in South Arm	Dogs in South Arm
O. cuniculus	54.55 a	27.27 a	70.59 a	29.63 a
European *Rattus* spp.	54.55 a	0.00 a	11.76 b	3.70 a
Superb fairy-wren	27.27 a	0.00 a	11.76 a	0.00 a
Tasmanian native hen	0.00 a	18.18 a	5.88 a	3.70 a
Bandicoots	27.27 b	0.00 a	17.65 b	0.00 a
Mus musculus	54. 55 a	0.00 b	35.29 a	3.70 b
Yellow-throated honeyeater	0.00 a	0.00 a	5.88 a	0.00 a
Noisy miner	0.00 a	0.00 a	17.65 b	0.00 a
I. obesulus	0.00 a	0.00 a	5.88 a	3.70 a
Dusky robin	9.09 a	0.00 a	0.00 a	0.00 a
Common starling	0.00 a	0.00 a	5.88 a	0.00 a
House sparrow	9.09 a	0.00 a	5.88 a	0.00 a
Frogs	0.00 a	0.00 a	5.88 a	0.00 a
Skinks / lizards	9.09 a	4.55 a	17.65 a	3.70 a
Bronzewing pigeons	0.00 a	0.00 a	5.88 a	0.00 a
P. breviceps	9.09 a	0.00 a	11.76 a	0.00 a
Grey fantail	0.00 a	0.00 a	5.88 a	0.00 a
Partially described small birds	18.18 a	4.55 a	17.65 a	0.00 a
P. gunnii	0.00 a	0.00 a	5.88 a	3.70 a
Rosellas	9.09 a	0.00 a	0.00 a	0.00 a

	Cats in Kingborough	Dogs in Kingborough	Cats in South Arm	Dogs in South Arm
Blue-tongue lizard	9.09 a	4.55 a	0.00 a	14.81 a
A. swainsonii	9.09 a	0.00 a	0.00 a	0.00 a
Possums	9.09 a	0.00 a	0.00 a	7.41 a
Ducks	9.09 a	0.00 a	0.00 a	0.00 a
Masked lapwing	9.09 a	0.00 a	0.00 a	0.00 a
Bats	9.09 a	0.00 a	5.88 a	0.00 a
Native rodents	9.09 a	0.00 a	0.00 a	0.00 a
Wallaby	9.09 a	4.55 a	0.00 a	0.00 a
Birds	9.09 a	0.00 a	0.00 a	0.00 a
Parrots	0.00 a	4.55 a	5.88 a	0.00 a
Robins	9.09 a	0.00 a	5.88 a	0.00 a
Flying insects	0.00 a	4.55 a	0.00 a	0.00 a
Echidna	0.00 a	4.55 a	0.00 a	0.00 a
Feral cat	0.00 a	4.55 a	0.00 a	0.00 a
T. vulpecula	0.00 a	4.55 a	0.00 a	11.11 a
D. viverrinus	0.00 a	0.00 a	0.00 a	3.70 a